EVALUATION OF THE MISSION, SANTEE, AND TIJUANA HYDROLOGIC SUBAREAS FOR RECLAIMED-WATER USE, SAN DIEGO COUNTY, CALIFORNIA

By John A. Izbicki

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[Plates are in pocket]

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric (SI) units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acres	0.4047	ha (hectares)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
acre-ft/yr (acre-feet per year)	0.001233	hm^3/yr (cubic hectometers per year)
ft (feet)	0.3048	m (meters)
ft^2/d (feet squared per day)	0.0929	m^2/d (meters squared per day)
ft^3/s (cubic feet per second)	0.02832	m^3/s (cubic meters per second)
gal/d (gallons per day)	0.003785	m^3/d (cubic meters per day)
(gal/d)/ft (gallons per day per foot)	0.04047	(L/d)/m (liters per day per meter)
gal/min (gallons per minute)	0.06309	L/s (liters per second)
(gal/min)/ft (gallons per minute per foot)	0.2070	(L/s)/m (liters per second per meter)
in. (inches)	25.4	mm (millimeters)
in/h (inches per hour)	25.4	mm/h (millimeters per hour)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
μmho/cm at 25°C (micromho per centimeter at 25° Celsius)	1.000	μS/cm at 25°C (microsiemen per centimeter at 25° Celsius)

Degrees Fahrenheit is converted to degrees Celsius by using the formula:

$$(\text{Temp °F}-32)/1.8 = \text{temp °C}$$

Abbreviations used:

mg/L - milligrams per liter
meq/L - milliequivalents per liter
μg/L - micrograms per liter
μm - micrometers

DEFINITIONS

Confidence criteria: Usually represented by the Greek letter α. The smaller the value of α, the smaller the chance of rejecting a hypothesis when the hypothesis is true (Neter and Wasserman, 1974).

Reclaimed water: Treated municipal wastewater; the required level of treatment is related to the degree of public contact as specified in Wastewater Reclamation Criteria, Title 22 of the California Administrative Code.

Transmissivity: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. (To obtain (gal/d)/ft from ft^2/d, multiply by 7.46.)

Water year: The water year starts October 1 and ends September 30; it is designated by the calendar year in which it ends.

EVALUATION OF THE MISSION, SANTEE, AND TIJUANA HYDROLOGIC SUBAREAS FOR RECLAIMED-WATER USE, SAN DIEGO COUNTY, CALIFORNIA

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ABSTRACT

Reclaimed-water use is contemplated as an alternative to irrigation with imported water and as a supplement to natural recharge in three small hydrologic subareas in San Diego County, California. This report details geology, soils, and hydrology as they may affect reclaimed-water use. A report by the California Department of Water Resources discusses cultural and engineering considerations.

The Mission subarea is 48 square miles in area, and contains a small (92,000 acre-feet of storage) alluvial aquifer. During spring 1983, water levels in wells ranged from above land surface to 19.4 feet below land surface. Ground-water discharge maintains base flow in the San Luis Rey River; historically, the river was ephemeral, and in many years did not flow at all. Recharge is primarily from agricultural return from irrigation with imported water in upland areas. Many wells and springs in upland areas flow year round. Dissolved-solids concentrations of ground water and of surface water at different flow regimes increased over time. Dissolved-solids concentrations of ground water ranged from 960 to 3,090 milligrams per liter. Plans aimed at improving ground-water quality by pumping water from the subarea and replacing it with reclaimed water that has dissolved-solids concentrations ranging from 843 to 1,050 milligrams per liter may not be feasible because of the possibility of increased infiltration of high dissolved-solids water from the San Luis Rey River. If reclaimed water applied to upland areas is to have adequate soil contact before discharging at land surface, special irrigation techniques and limited application rates may be required.

The Santee subarea is 77 square miles in area and contains a small (55,000 acre-feet of storage) alluvial aquifer. During spring 1983, water levels in wells ranged from 2.6 to 25 feet below land surface. Natural recharge has been greatly altered by construction of water-supply reservoirs upstream of the alluvial aquifer. During 1948-78, significant recharge did not occur. Dissolved-solids concentrations ranged from 260 milligrams per liter in the eastern part of the aquifer to more than 2,500 milligrams per liter in the western part. Increases in dissolved-solids concentrations with time have been measured. Reclaimed-water-use plans aimed at improving ground-water quality by pumping poor-quality ground water from the subarea and replacing it with reclaimed water that has a dissolved-solids concentration of about 900 milligrams per liter may be feasible in the western part of the aquifer. If reclaimed water is used as a new source of water supply to develop vacant lands, irrigation-return flow could become a major source of recharge. In the eastern part of the

aquifer, where ground water is used for domestic supplies, reclaimed-water use may be undesirable.

The Tijuana subarea is 16 square miles in area and contains the western part of an alluvial aquifer that extends across the border into Mexico. The part of the aquifer in the United States contains between 50,000 and 80,000 acre-feet of ground water in storage. In spring 1983, water levels in wells ranged from above land surface to 12.7 feet below land surface. Recharge is provided primarily by surface flow in the Tijuana River. Water levels rose as much as 7 feet in response to the wet winter of 1982-83 and high streamflows. Water is sodium chloride in chemical character, with a median dissolved-solids concentration of 2,150 milligrams per liter. Changes in ground-water quality as a result of seawater intrusion, irrigation return, and leakage of ground water from surrounding marine sediments have been measured. Reclaimed-water-use plans aimed at improving ground-water quality by pumping water from the subarea and replacing it with reclaimed water that has a dissolved-solids concentration of about 900 milligrams per liter may be feasible, providing seawater intrusion can be controlled. In some areas, if reclaimed water is to have adequate soil contact before discharging at land surface, special irrigation techniques and limited application rates may be required.

INTRODUCTION

The San Diego region is experiencing rapid population growth and attendant increase in demand for water. While demand for water is increasing, availability of imported water from the Colorado River will decrease with completion of the Central Arizona Project in 1985. To help meet expected shortfalls, reclaimed-water use is contemplated in the Mission (of the San Luis Rey River valley), Santee, and Tijuana hydrologic subareas in San Diego County, Calif. This report details aspects of geology; soils; streamflow characteristics; ground-water hydrology; and surface-, ground-, and reclaimed-water quality as they may affect future reclaimed-water-use plans. A report by the California Department of Water Resources (1984) discusses population, land use, elements of water supply and demand, beneficial uses of existing water supplies, and water-quality objectives. Two similar reports evaluating potential for reclaimed-water use in the San Dieguito, San Elijo, and San Pasqual hydrologic subareas are completed (Izbicki, 1983; California Department of Water Resources, 1983a).

Purpose and Scope

The purpose of this study is to update hydrologic data, to refine the understanding of the hydrologic system within the Mission, Santee, and Tijuana hydrologic subareas in San Diego County, and to evaluate the suitability of these areas for reclaimed-water use. This report, prepared in cooperation with the San Diego County Water Authority and the California Department of Water Resources, provides hydrologic data necessary to assist local agencies in developing reclaimed-water-use plans that could help optimize San Diego's water resources. Data collected during the study also could serve as a baseline from which changes in water quality and quantity caused by reclaimed-water use may be evaluated.

The scope of this study included compiling existing geologic and hydrologic data, inventorying wells and springs, collecting data for ground-water levels, surface-water flow, and ground- and surface-water quality. This report summarizes data collected and evaluates suitability of each hydrologic subarea for reclaimed-water use.

Location of Hydrologic Subareas

The Mission, Santee, and Tijuana hydrologic subareas were studied in 1982-83 to determine their suitability for reclaimed-water use. All subareas are in the Pacific slope basin of San Diego County (fig. 1). An alluvial aquifer in each subarea is the most important source of ground water. In the text, the alluvial aquifer is referred to as the alluvial basin. Areas within the subarea but outside the alluvial basin are referred to as uplands.

The Mission hydrologic subarea (State hydrologic unit number Z-3.A1; California Department of Water Resources, 1964) is almost 48 mi^2 in area. It is the downstream part of the San Luis Rey River drainage basin. The Mission subarea includes the downstream part of the San Luis Rey River valley ground-water basin (Basin 9-7; California Department of Water Resources, 1975). Parts of the city of Oceanside and the community of San Luis Rey are within the Mission subarea. Land use is urban near the ocean and residential and agricultural farther inland.

The Santee hydrologic subarea (State hydrologic unit number Z-7.A2; California Department of Water Resources, 1964) is 77 mi^2 in area, and for the purposes of this report includes the El Monte hydrologic subarea (State hydrologic unit number Z-7.A5; California Department of Water Resources, 1975). It is the central part of the San Diego River drainage basin. The Santee subarea includes the San Diego River valley ground-water basin (Basin 9-15; California Department of Water Resources, 1975). The communities of Santee and Lakeside are within the subarea. Land use is residential in the western and central parts of the subarea, and agricultural in the eastern part.

The Tijuana hydrologic subarea (State hydrologic unit number Z-11.A1; California Department of Water Resources, 1964) is in the southwest corner of San Diego County along the Mexican border and is about 16 mi^2 in area. The subarea includes the Tijuana River drainage basin (Basin 9-9; California Department of Water Resources, 1975). Parts of the city of San Diego, and the communities of Imperial Beach, Nestor, and San Ysidro lie within the subarea. Land use is primarily agricultural, but residential and urban uses are expanding in the northern and eastern parts of the subarea.

Previous Work and Acknowledgments

Published reports and maps pertaining to the study area, listed in the "Selected References" section of this report, include data on geology, precipitation, wells, and springs. Agencies contributing unpublished data to this study are the California Department of Water Resources, the city of Oceanside Water and Sewer Department, and the U.S. Geological Survey. James Turner of the city of Oceanside and Al Goff of the International Boundary and Water Commission provided data from hydrologic monitoring networks in the Mission and Tijuana subareas to supplement data-collection efforts. Technical assistance was provided by Larry Michaels of the San Diego County Water Authority and by Ahmad Hassan, Stig Johanson, Sanford Werner, and Evelyn Tompkins of the California Department of Water Resources.

Data Collection

Data collected during autumn 1982 and spring 1983 included surface-water flow, ground-water levels in selected wells, ground-water quality, and surface-water quality. Water-quality samples were analyzed for sodium, potassium, calcium, magnesium, chloride, alkalinity, sulfate, fluoride, nutrients (Kjeldahl, ammonia, nitrite, nitrite + nitrate, and orthophosphate), residue on evaporation at 180°C (dissolved solids), total organic carbon, silica dioxide, boron, and iron. Field measurements were made of pH, alkalinity, and specific conductance. Percent sodium, sodium-absorption ratio, and the sum of dissolved constituents

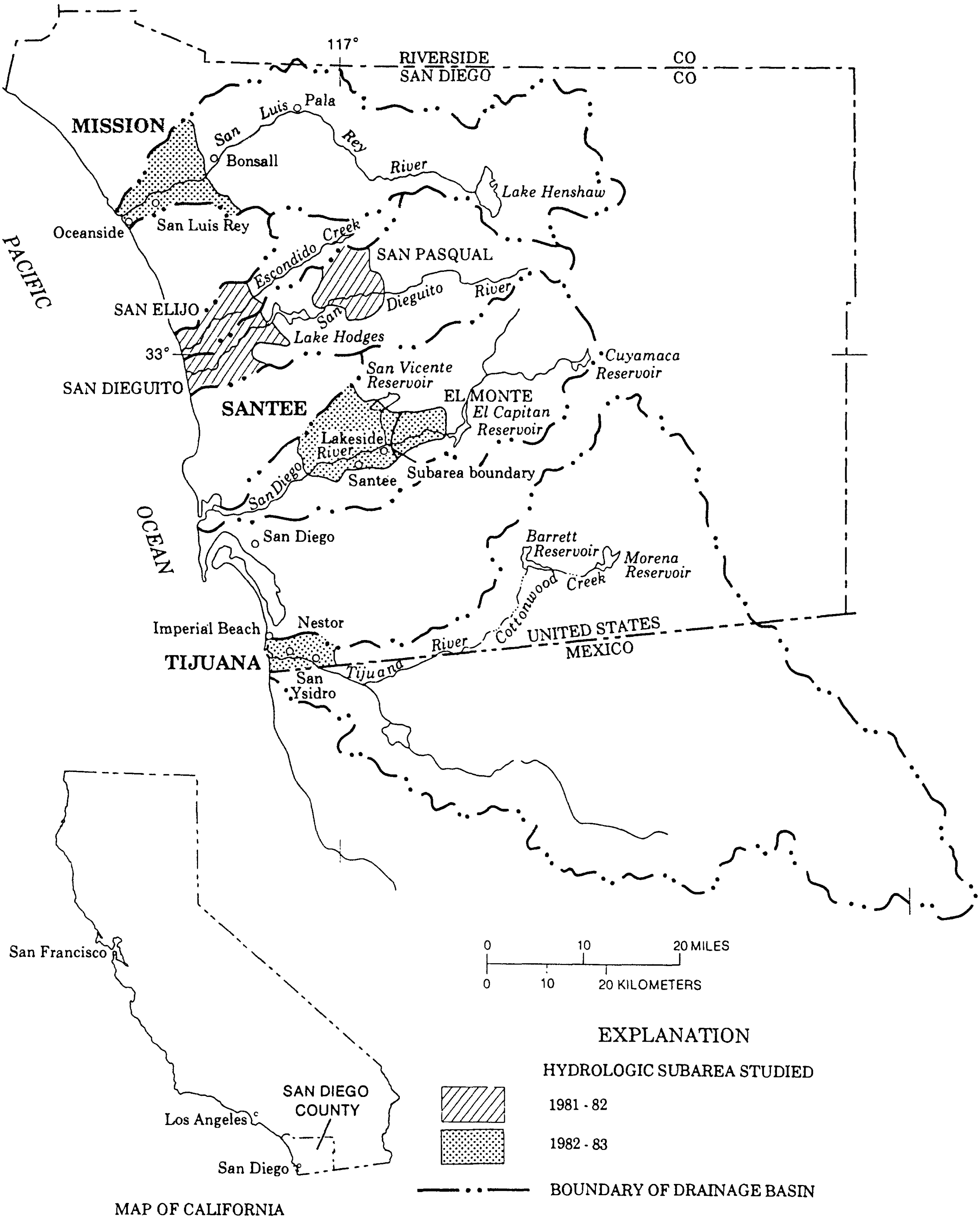


FIGURE 1. - Location of hydrologic subareas.

were calculated. At selected sites, analysis was made for the following trace elements: antimony, arsenic, aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, and zinc. Although not all data are discussed in the text, they provide a baseline from which to assess the effect of reclaimed-water use on the study areas. Data are given in tables 14-15 (at end of report).

Field Methods

Instantaneous measurements of discharge exceeding 0.5 ft^3/s were made with current meters using guidelines outlined by Carter and Davidian (1968). Instantaneous measurements of discharge less than 0.5 ft^3/s were made with a modified Parshall flume using guidelines outlined in Kilpatrick (1965).

Depth to water in wells was measured using a steel tape. Data from recently pumped wells were omitted from the analyses.

Surface-water-quality samples were collected using a DH-48 sampler. The sampler was painted with a nonmetallic white epoxy paint, and a teflon nozzle and silicon gasket were used to minimize contamination. The equal-width-increment method was used to collect the samples.

Where possible, ground-water-quality samples were collected from pumping wells. Wells were pumped long enough to be reasonably certain formation water was collected. Where pumping wells were not available, open wells were pumped with an air compressor. Specific conductance of discharge water was monitored and samples were collected after specific conductance stabilized, and at least the casing volume was pumped. Samples were then collected at the perforated interval using a Kemmerer bottle.

Samples for most dissolved constituents were filtered in the field through 0.45-µm pore-size membrane filters. Samples for aluminum, iron, and manganese were filtered in the field using 0.1-µm filters to eliminate microcrystalline and colloidal forms of these elements. Samples for cations were acidified to a pH of less than 2. Portable meters were used for field measurements of pH, specific conductance, and alkalinity (Skougstad and others, 1979, p. 511, 512, 517, 518). Water-temperature measurements were made with hand-held mercury-filled thermometers that have a full-scale accuracy of 0.5°C; the thermometers were calibrated with an American Society for Testing and Materials standard laboratory thermometer. All samples were chilled, and sent within 24 hours to the U.S. Geological Survey Water-Quality Laboratory in Arvada, Colo.

Laboratory Methods

Nutrient samples were analyzed using automated colorimetric methods (Skougstad and others, 1979, p. 389-399, 407, 415-517, 433-439, 445-447, 479-481, 491-493). Samples for sodium, potassium, calcium, magnesium, barium, berylium, lithium, mercury, and zinc were analyzed by atomic absorption spectrometric methods (Skougstad and others, 1979, p. 229-230, 255-256, 107-108, 177-178, 85-86, 91-92, 171-172, 197-200, 273-274). Aluminum, cadmium, chromium, copper, lead, manganese, molybdenum, nickel, and silver were analyzed by atomic absorption spectrometric methods with chelation extraction (Skougstad and others, 1979, p. 39-40, 97-98, 121-122, 143-144, 158-162, 185-186, 209-210, 215-218, 251-252). Antimony, arsenic, and selenium were analyzed by automated atomic absorption methods with hydride generation (Skougstad and others, 1979, p. 49-52, 65-68, 237-241). Automated colorimetric methods (Skougstad and others, 1979, p. 333-335, 375-377, 497-499, 501-504, 505-506) were used to analyze samples for iron, chloride, silica, and sulfate. Samples for boron were analyzed by a non-automated colorimetric method (Skougstad and others, 1979, p. 315-316). Fluoride determinations were done by electrometric ion-selective electrode method (Skougstad and others, 1979, p. 525-528). Total organic carbon was analyzed by the wet oxidation method (Wershaw and others, 1983, p. 25-27).

Data Limitations

Data were collected during a wet period which began in 1978. In 1982-83, many streams that typically flow for only brief periods flowed throughout the year. Alluvial aquifers were filled to near capacity, and seasonal variations in water levels were small during the study period. Data collected in autumn 1982 and spring 1983 reflect water quantity and quality during a wet cycle.

To gain a greater understanding of hydrologic processes in dry years, historical water-level and water-quality data from other agencies were used. Although data were checked for accuracy, there are inherent problems in analyzing data collected by other agencies using different and frequently unknown methods.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. For example, in well number 1S/4W-33G2S, that part of the number preceding the slash indicates the township (T. 1 S.); the number and letter following the slash indicate the range (R. 4 W.); the number following the hyphen indicates the section (sec. 33); the letter following the section number (G) indicates the 40-acre subdivision of the section; the final digit (2) is a serial number for wells in each 40-acre subdivision; and the final letter (S) indicates the San Bernardino base line and meridian. Where township and range are given along the margins of maps, wells are identified using only the section; 40-acre subdivision; and serial number for wells in the subdivision. If a well location could not be correlated with existing data, the serial number was omitted. All wells in this report are numbered from the San Bernardino base line and meridian.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Climate and Precipitation

The study areas have a Mediterranean climate, with warm, dry summers and mild winters. Mean annual temperature ranges from 54° to 64°F. Inland areas have a larger range of temperature than coastal areas. Because of coastal fog, humidity is fairly high along the coast during the summer, but decreases rapidly farther inland.

Precipitation is unevenly distributed throughout the year, with most occurring between November and April. In coastal areas, annual precipitation ranges from 11 to 15 inches. Annual precipitation increases inland, and varies from more than 35 inches for the headwaters of the San Diego River and 45 inches for San Luis Rey River (fig. 2). Light snowfall generally occurs in the winter at higher altitudes. In 1982-83, precipitation was as much as 210 percent greater than normal in parts of San Diego County (California Department of Water Resources, 1983b).

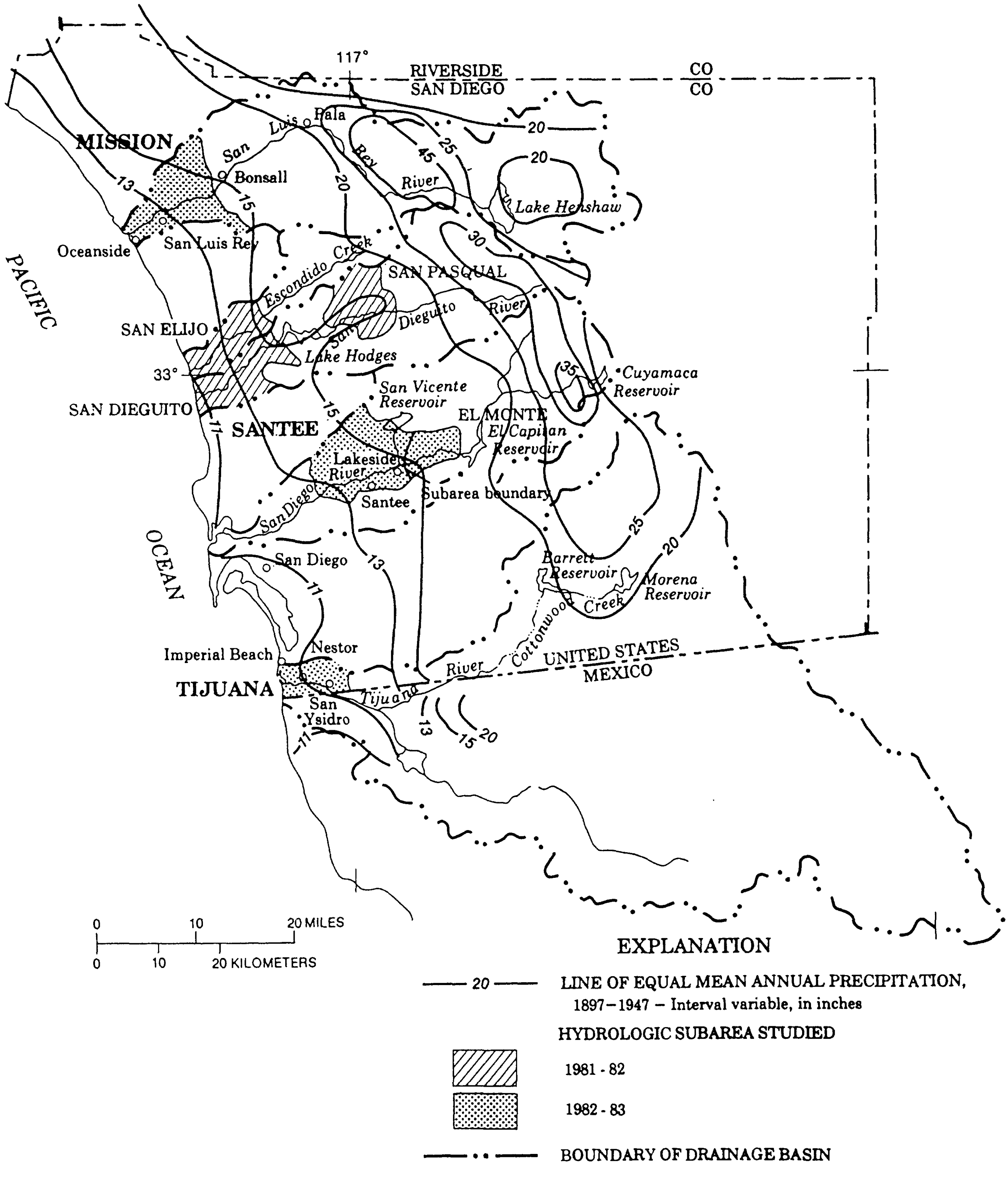


FIGURE 2. - Mean annual precipitation (Modified from California Department of Water Resources (1967a)).

MISSION HYDROLOGIC SUBAREA

Geology

The Mission hydrologic subarea is divided into two physiographic provinces; the eastern part lies within the Peninsular Range Province and the western within the Pacific Coastal Plain (pl. 1).

Peninsular Range Province

Crystalline rocks, primarily the Upper Cretaceous Bonsall Tonalite, are exposed in the Peninsular Range Province of the Mission subarea. These rocks have weathered to a gently rolling, westward-sloping topography, and form the basement complex upon which marine sedimentary rocks of the coastal plain were deposited. Isolated weathered remnants of volcanic plugs form prominent topographic features such as Morro Hill.

Pacific Coastal Plain

The western part of the Mission subarea is within the Pacific Coastal Plain. Here the coastal plain is 6 to 7 miles wide and has two distinct zones: one underlain by the Miocene San Onofre Breccia, the other by the Eocene La Jolla Group.

The San Onofre Breccia parallels the coast and has eroded to form a stairstep series of mesa-like hills topped by marine terrace deposits. The San Onofre Breccia is well cemented and dips to the west, continuing for some distance under the ocean. The marine terrace deposits are flat-lying, partly cemented cobble conglomerates.

Farther inland where marine sedimentary rocks of the La Jolla Group are exposed, marine terrace deposits have eroded to form rolling hills rather than the mesa-like topography typical of the Pacific Coastal Plain in southern San Diego County. The La Jolla Group is composed of partly consolidated sandstones, mudstones, siltstones, and shales; total thickness is about 1,650 feet (California Department of Water Resources, 1967a).

The Pacific Coastal Plain has been incised by the San Luis Rey River, and the valley formed has been partly backfilled with alluvium. The alluvial valley floor is about 8 miles long and 1.5 miles wide. To the west where the San Luis Rey River has cut through the San Onofre Breccia, the alluvial valley narrows to a width of only several hundred feet.

Soils

Soil develops in response to topographic expression, microclimate, native vegetative cover, and geologic parent material from which it weathers. Soil is the first media with which reclaimed water will come in contact, and also the media in which most biologically mediated reactions occur. Storage or movement of reclaimed water in an underlying aquifer is decreased if a soil is too shallow, has low permeability, excessive slope, undesirable chemical reactions, a hardpan, or a high water table. Five soil associations have been identified in the Mission subarea (pl. 2): Fallbrook-Vista; Marina-Chesterton; a miscellaneous association of broken land and terrace escarpments; Diablo-Linne and Diablo-Las Flores; and Visalia-Tujunga. The discussion that follows is based primarily on work by the U.S. Soil Conservation Service (1973).

The Fallbrook-Vista association has developed over crystalline rocks of the Peninsular Range Province. The association is characterized by Fallbrook and Vista soils, 1.5 to 4 feet thick, and Cienba soils, generally less than 1.5 feet thick. Thick soils are atypical of this association, and only small areas of Bonsall soils developed over weathered tonalite attain thicknesses of 5 feet. Infiltration capacities are moderate to high throughout most of the Fallbrook-Vista association and range from 0.6 to

2.0 in/h for Fallbrook soils to 20 in/h for Cienba soils. Bonsall soils are characterized by a clay hardpan at depths of 1 to 3 feet; infiltration rates across the hardpan are less than 0.06 in/h.

The Marina-Chesterton association has developed over unnamed marine terrace deposits of the Pacific Coastal Plain. The association is typified by gently sloping, excessively drained sandy loam which may contain impermeable iron-silica hardpans. Marina soils are more than 5 feet thick; infiltration exceeds 20 in/h throughout the soil profile. Chesterton soils are 2 to 3 feet thick and have a well-developed hardpan at a depth of 1.5 feet; infiltration across the hardpan is less than 0.06 in/h.

Where marine terrace deposits are partly eroded and the San Onofre Breccia is exposed, soils belong to a miscellaneous association of broken land and terrace escarpments and sloping gullied land. Soils developed from remnants of marine terrace deposits are thin (1.5 to 3.5 feet) and characterized by a hardpan at a depth of 3 feet. Low infiltration (less than 0.06 in/h) and rapid runoff have resulted in erosion of exposed slopes. Small areas of thick soils (greater than 5 feet) that have moderate slopes and high infiltration (6.3 to 20 in/h) throughout the soil profile occurs near stream channels and on small hills.

The Diablo-Linne and Diablo-Las Flores associations have developed over marine sedimentary rocks of the La Jolla Group. These soils contain considerable amounts of clay, and infiltration ranges from less than 0.06 in/h for Las Flores soils to 0.2 to 0.6 in/h for Linne soils.

The Visalia-Tujunga association has developed over alluvial deposits in the San Luis Rey River valley. Soils of the Visalia-Tujunga association are more than 5 feet thick and are sandy. Infiltration ranges from 2.0 to 6.3 in/h for Gaviota soils to more than 20 in/h for Tujunga soils. Infiltration in this soil association generally is the highest of any soils in the Mission subarea. The primary limitation on application of reclaimed water to soils of the Visalia-Tujunga association is a high water table, often within a few feet of land surface much of the year. The association also contains small areas of saline soils.

Surface Water

Streamflow Characteristics

The Mission hydrologic subarea is drained by the San Luis Rey River. The river drains 558 mi^2, and flow has been regulated since 1923 by Lake Henshaw. Lake Henshaw had a design capacity of 194,300 acre-ft, but in 1982 capacity was decreased to 53,440 acre-ft to help meet earthquake safety standards (Larry Michaels, San Diego County Water Authority, written commun., 1984). Maximum discharge in the San Luis Rey River was 95,600 ft^3/s on February 12, 1980, and maximum annual discharge was 515,000 acre-ft in water year 1980. Discharge data are summarized in table 1, and location of gaging stations is shown in figure 3.

Number of days with flow greater than 0.1 ft^3/s in the San Luis Rey River at Monserate Narrows; near Bonsall; and at Oceanside is shown in figure 4. Prior to 1965, the river flowed the greatest number of days at Monserate Narrows, and number of days with flow decreased downstream. In many years, no flow was recorded near Bonsall and at Oceanside. After 1965, more days with flow were recorded at Oceanside and near Bonsall than at Monserate Narrows. In general, the number of days with flow increased downstream. For example, in 1971 and 1972 no flow was recorded at Monserate Narrows, but more than 330 days of flow were recorded near Bonsall, and the San Luis Rey River at Oceanside flowed year round.

Prior to 1965, the median number of days with flow greater than 0.1 ft^3/s was 194 days at Monserate Narrows, 129 days near Bonsall, and 0 days at Oceanside.

TABLE 1.--Summary of discharge data for the San Luis Rey River

[Station name: Flow regulated since 1923 by Lake Henshaw which had a design capacity of 194,300 acre-ft. In 1982 capacity was reduced to 53,440 acre-ft to help meet earthquake safety standards. There are additional small diversions above the station]

Station name	Station No.	Period of record	Drainage area (mi²)	Annual discharge (acre-ft)		Median number of days with discharge greater than 0.1 ft³/s		Maximum discharge for period of record	
				average	median	Prior to 1965	After 1965	instantaneous (ft³/s)	annual (acre-ft)
San Luis Rey River at Monserate Narrows, near Pala	11040000	April 1938 to November 1941 October 1946 to September 1981	373	7,200	1,406	194	132	15,500	208,000
San Luis Rey River near Bonsall	11041000	October 1929 to September 1979	513	16,810	7,180	[1]129	[1]365	([2])	([2])
San Luis Rey River at Oceanside	11042000	April 1912 to September 1914 October 1929 to January 1942 October 1946 to September 1981	558	16,160	3,880	[1]0	[1]365	95,600	515,000

[1]Statistically significant difference using median test (Neter and Wasserman, 1974) with $\alpha = 0.001$ as the confidence criteria.
[2]Gage destroyed during flood of 2-12-80.

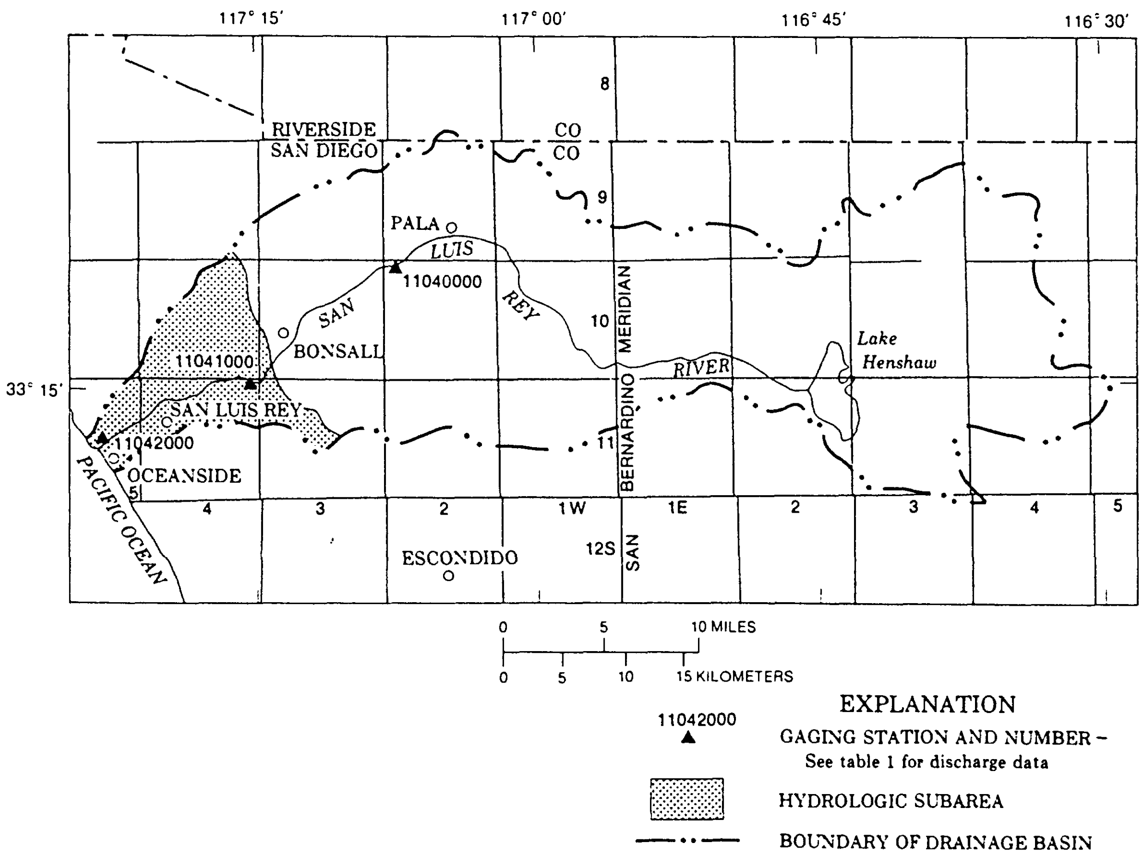


FIGURE 3. - Location of gaging stations in or near the Mission hydrologic subarea.

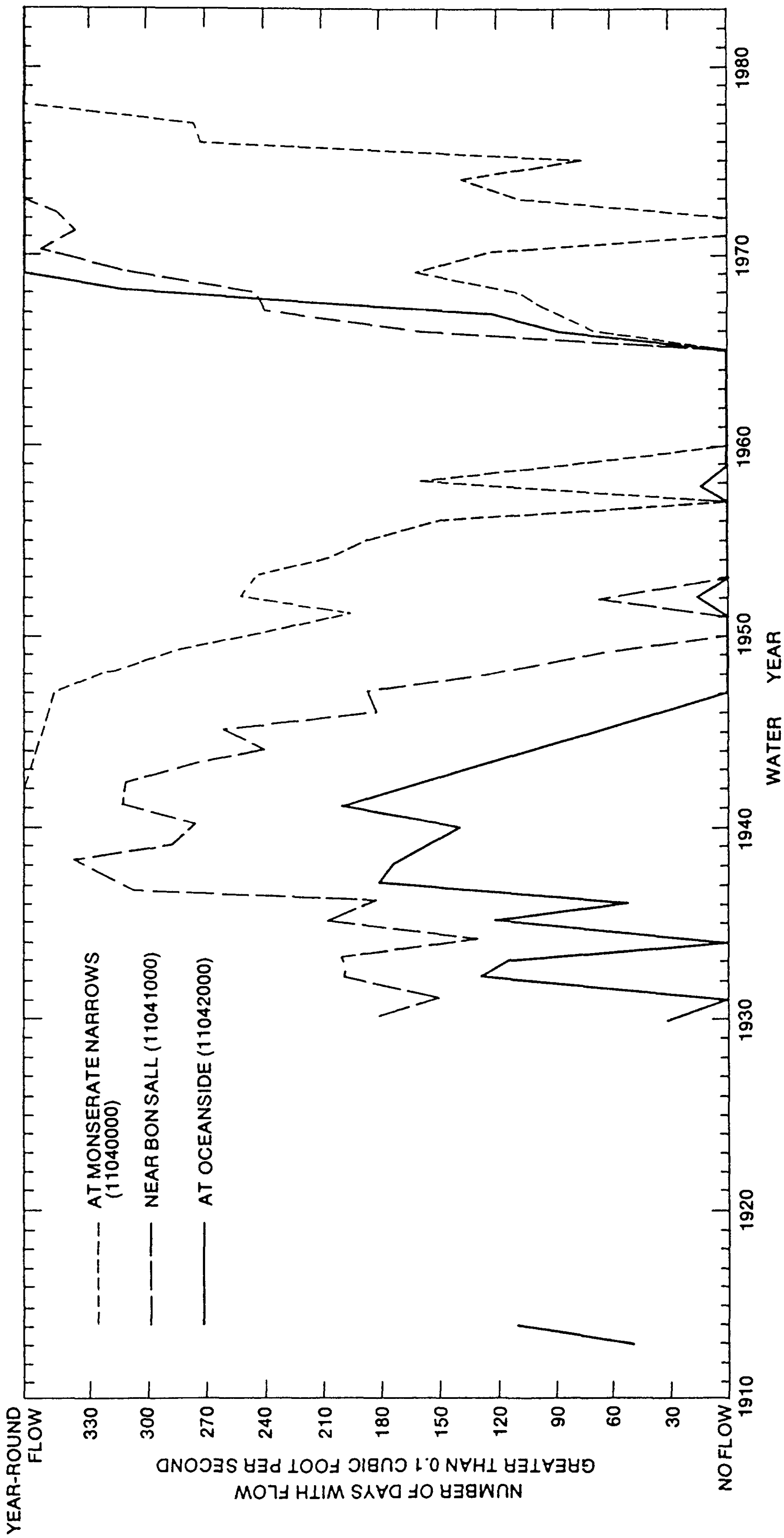


FIGURE 4. - Number of days with flow in the San Luis Rey River at Monserate Narrows, near Bonsall, and at Oceanside.

After 1965, the median number of days with flow greater than 0.1 ft^3/s was 132 days at Monserate Narrows, 365 days near Bonsall, and 365 days at Oceanside (table 1). Increases in number of days with flow near Bonsall and at Oceanside were statistically significant using the median test (Neter and Wasserman, 1974) with $\alpha = 0.001$ as the confidence criteria. Increases in number of days with flow near Bonsall and at Oceanside reflect increasing use of imported water downstream from the gaging station at Monserate Narrows. Number of days with flow decreased at Monserate Narrows, and it was not until 1978 and the beginning of a generally wetter period of record that year-round flow was again recorded at Monserate Narrows. The decrease in median number of days with flow at Monserate Narrows was not statistically significant.

Surface-Water Quality

The San Luis Rey River at Oceanside is part of the National Stream-Quality-Accounting Network (NASQAN) operated by the U.S. Geological Survey. Water-quality data are summarized in table 2. Dissolved-solids concentrations ranged from 394 to 3,040 mg/L; the median concentration was 1,230 mg/L. Dissolved solids exceeded 1,000 mg/L in 65 percent of the analyses. Chloride and sulfate exceeded U.S. Environmental Protection Agency (1976) recommended limits for drinking water supplies of 250 mg/L in 65 and 75 percent of the analyses. Public water supply criteria are summarized in table 3.

Concentrations of dissolved solids, chloride, and other dissolved constituents increase as water in the San Luis

TABLE 2. - Summary of water-quality data for two gaging stations on the San Luis Rey River

[Instantaneous discharge, in cubic feet per second; specific conductance, in micromhos per centimeter at 25°C; pH, in units; and constituents, in milligrams per liter unless otherwise noted. --, no data]

Station name	Period of record		Instantaneous discharge	Specific conductance	pH	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Alkalinity as $CaCO_3$	Sulfate, dissolved	Chloride, dissolved	Silica, dissolved	Dissolved solids	Nitrate as N	Boron, dissolved, micrograms per liter
San Luis Rey River at Monserate Narrows, near Pala	April 1973 to June 1981	Minimum	0.3	680	7.2	34	15	36	5.4	140	21	70	15	375	0.05	50
		Median	2.5	1,480	7.7	110	54	122	8.7	188	305	190	30	958	0.45	140
		Maximum	213	2,030	8.3	140	82	180	65	221	440	290	34	1,290	5.8	300
		Number of samples	12	12	11	12	12	12	12	10	12	12	12	12	9	11
San Luis Rey River at Oceanside[1]	February 1958 to February 1962	Minimum	0.1	369	7.1	7.7	7.9	53	3.0	63	52	55	10	222	1.1	100
		Median	0.1	458	7.1	21	15	53	3.0	137	55	60	15	392	--	100
		Maximum	127	713	7.2	24	10	68	5.0	195	96	159	16	480	7.0	160
		Number of samples	4	4	4	3	3	3	3	4	3	4	3	4	2	3
	October 1971 to July 1983	Minimum	2.2	650	7.1	33	22	54	4.0	120	100	72	2.8	394	--	--
		Median	98.7	1,740	8.2	130	66	170	7.2	200	360	300	27	1,230	--	--
		Maximum	2,260	4,660	8.5	147	120	640	31	260	510	1,200	40	3,040	--	--
		Number of samples	76	563	50	51	51	51	51	42	51	51	51	50	--	--

[1]Data from California Department of Water Resources.

Rey River flows from Monserate Narrows to Oceanside. The relations between dissolved solids and streamflow are shown in figure 5. The relations were developed using the polynomial function:

$$y = B_o + B_1Q + B_2Q^2$$

where

y is the dependent variable (dissolved solids, in milligrams per liter);

Q is the independent variable (streamflow, in cubic feet per second); and

B_o, B_1, and B_2 are statistical estimators of intercept, slope, and curvature (Neter and Wasserman, 1974).

The functions were fit by the method of least squares and the following statistical models were obtained:

at Oceanside,
$y = 1{,}540 - 4.4Q + 0.005Q^2$

at Monserate Narrows,
$y = 1{,}070 - 11.6Q + 0.04Q^2$

The F test (Neter and Wasserman, 1974), with $\alpha = 0.05$ as the confidence criteria, was used to establish that B_2 was significantly different from 0 and should remain in the model. The 90-percent confidence limits about each model are shown in figure 5. These confidence limits were developed using a method outlined by Neter and Wasserman (1974). Five percent of the time a plot of dissolved-solids concentrations as a function of streamflow will lie above the upper 90-percent confidence limit; 5 percent of the time it is less than the lower 90-percent confidence limit; and 90 percent of the time is somewhere between the upper and lower 90-percent confidence limits. Over the range of available data, highly significant differences between dissolved-solids concentrations of water in the San Luis Rey River at Monserate Narrows and at Oceanside are indicated by the lack of overlap between the respective statistical models and their associated 90-percent confidence limits. Statisti-

TABLE 3. - Public water-supply criteria

[Data from McKee and Wolf, 1963; National Academy of Sciences, National Academy of Engineering, 1973; U.S. Environmental Protection Agency, 1976]

Propertities and constituents	Maximum concentration
Arsenic (As)--------------μg/L--	50
Barium (Ba)---------------mg/L--	1
Boron (B)-----------------μg/L--	750
Cadmium (Cd)--------------μg/L--	10
Chloride (Cl)-------------mg/L--	250
Chromium (Cr^{+6})-----------μg/L--	50
Cyanide (CN)--------------mg/L--	0.2
Copper (Cu)---------------mg/L--	1
Dissolved solids----------mg/L--	500
Fluoride (F)--------------mg/L--	[1]1.4 to 2.4
Hardness------------------mg/L--	300
Iron (Fe)-----------------mg/L--	0.3
Lead (Pb)-----------------μg/L--	50
Manganese (Mn)------------μg/L--	50
Mercury (Hg)--------------μg/L--	2
Nitrate-Nitrogen (N)------mg/L--	10
Nitrate (NO_3)-------------mg/L--	45
Selenium (Se)-------------μg/L--	10
Specific conductance -------------μmho/cm at 25°C--	800
Sulfate (SO_4)-------------mg/L--	250
Zinc (Zn)-----------------mg/L--	5

[1]Depends on annual average of maximum daily air temperature.

cal analyses for chloride, a biologically and chemically conservative ion, yielded similar results.

Polynomial functions in figure 5 yield a minimum (or maximum if B_4 is positive) value of y at:

$$Q_{min} = \frac{-B_1}{2B_2}$$

At Monserate Narrows Q_{min} is equal to 193 ft^3/s and at Oceanside Q_{min} is equal to 440 ft^3/s. Because of the behavior of the polynomial function at values of Q greater than Q_{min}, relations between discharge and dissolved solids should not be extended to values of Q greater than Q_{min}.

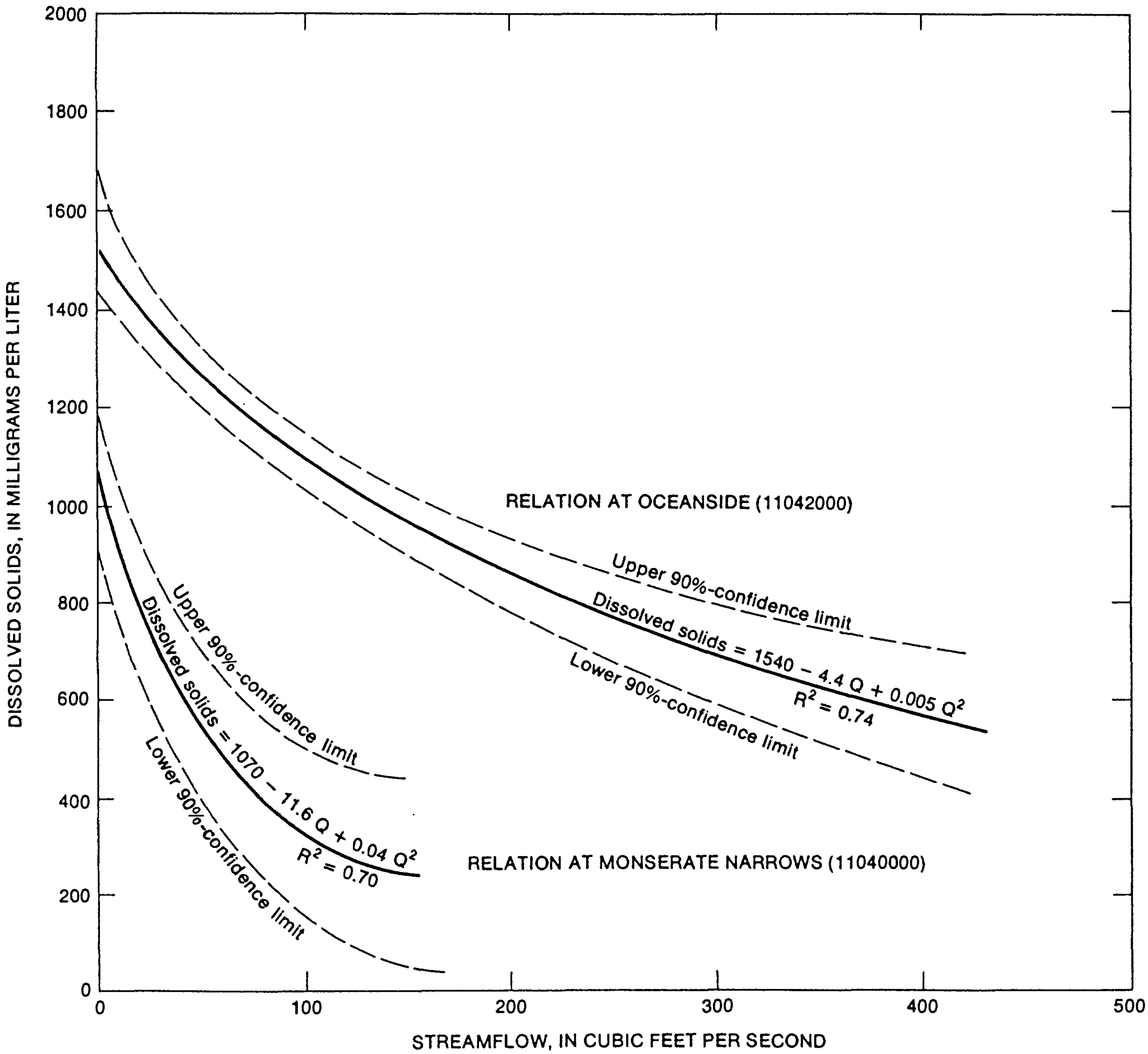


FIGURE 5. - Dissolved solids as a function of streamflow at Monserate Narrows and at Oceanside.

Historically, the relation between dissolved solids and discharge at Oceanside was much different. A 1971-83 plot of discharge versus dissolved solids is shown in figure 6. Current conditions are presented as the regression line developed previously; for comparison, pre-1965 data also are plotted. Pre-1965 data did not fall within the 90-percent confidence interval about the regression line. At any given discharge, there has been a substantial change in dissolved-solids concentration. Pre-1965 data, though collected during low flows, actually represent peak flows of storms sufficient in magnitude to generate flow at Oceanside. Under 1971-83 conditions, the dissolved-solids concentrations of stormflow water at Oceanside do not approach the pre-1965 dissolved-solids concentrations of stormflow water until discharge exceeds 440 ft^3/s. Statistical analysis for chloride yielded similar results.

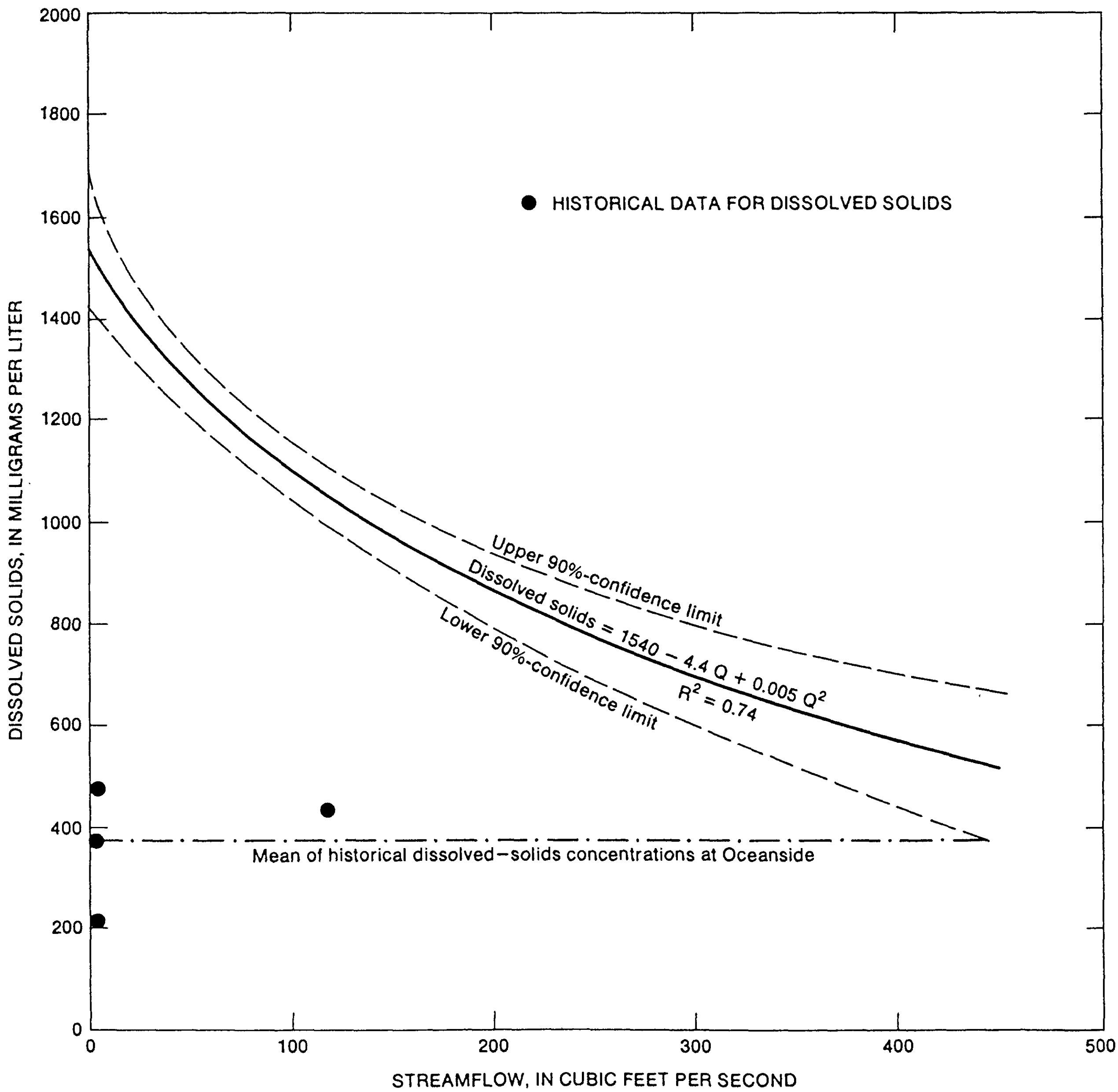


FIGURE 6. - Dissolved solids as a function of streamflow at Oceanside before and after the large-scale use of imported water for irrigation in the lower San Luis Rey River drainage basin.

Ground Water

Peninsular Range Province

Water-bearing characteristics in the Peninsular Range Province change with degree of fracturing and weathering of Bonsall Tonalite. Where Bonsall Tonalite is only slightly weathered, ground-water flow is primarily through cracks and fissures. Well yields typically do not exceed 15 gal/min (table 4). Specific capacities for wells in similar material are generally less than 0.1 (gal/min)/ft of drawdown (Izbicki, 1983). Although weathering has not been extensive in the Mission subarea, it has occurred to differing degrees. Where Bonsall Tonalite is weathered, ground-water flow is through pore spaces in the decomposed granitic matrix. Well yields and specific capacity are greatest where the degree of weathering is greatest.

Since introduction of large-scale irrigated agriculture with imported water, ground-water recharge has increased. Many wells and springs that previously did not flow now flow much of the year.

Pacific Coastal Plain

The San Onofre Breccia is a very tight, almost impermeable formation that does not yield significant quantities of water to wells. Except where fractured or incised by streams, the San Onofre Breccia has acted as a barrier to seawater intrusion. Marine terrace deposits overlying the San Onofre Breccia are generally above the regional water table and do not yield water to wells.

Data are not available for the Mission subarea on water-bearing characteristics of wells completed in the La Jolla Group.

TABLE 4.--Water-bearing characteristics of aquifers in the Mission hydrologic subarea

[Data from drillers' information. --, no data]

Geologic unit	Map symbol (see pl. 1)	Exposure in subarea (acres)	Maximum thickness (feet)	Lithologic character	General water-bearing characteristics	Discharge (gal/min)	Specific capacity (gal/min)/ft of drawdown	Trans-missivity (ft^2/d)
Alluvium	Qal	9,800	220	River and stream deposits of gravel, sand, silt, and clay.	Yields water freely to wells.	As much as 2,000; typically 500.	As much as 150; typically 25.	As much as 38,000; typically 5,200.
Unnamed marine terrace deposits	Qt	1,950	25±	Partly cemented cobble conglomerate.	Permeable, but generally above regional water table.	--	--	--
San Onofre Breccia	Tso	750	2,600	Well-cemented breccia of older schists and shales.	Non-water-bearing barrier to sea-water intrusion.	--	--	--
La Jolla Group	Tlj	7,000	1,650	Massive marine sand-stones, mudstones, siltstones, and shales. Sandstones typically coarse and partly consolidated.	Yields small quantities of water to wells.	As much as 50; typically between 10 and [1]20.	As much as [1]0.4.	--
Crystalline rocks	Kt, KJsp	11,000	Basement complex	Primarily unweathered tonalite with some volcanics.	Yields small quantities of water to wells from fractures and weathered matrix.	As much as 15; typically less than 3.	Less than 0.1.	--

[1]Data from nearby subareas (Izbicki, 1983).

In other parts of San Diego County, well discharge from the La Jolla Group ranges from 10 to 20 gal/min and may be as much as 50 gal/min. Specific capacities may be as much as 0.4 (gal/min)/ft of drawdown. Some wells in the La Jolla Group have flowed, and under certain conditions leakage of ground water from the La Jolla Group into alluvial aquifers may be a significant source of recharge to the alluvial aquifer (Izbicki, 1983).

Alluvial Aquifer

Within the Mission subarea, alluvial fill occupies a southwesterly trending valley approximately 9 miles long and 1 to 2 miles wide; alluvial thickness generally exceeds 200 feet (fig. 7). In the east, where the San Luis Rey River enters the subarea, alluvial fill is less than 1,000 feet wide and 100 feet thick. In the west, where the San Luis Rey River enters a narrow canyon before discharging to the Pacific Ocean, and alluvial fill again narrows to less than 1,000 feet, but retains its thickness of more than 200 feet. The aquifer contains about 694,000 acre-ft of alluvial fill. Assuming specific yields of 0.12 for parts of the aquifer nearer the ocean and 0.16 farther inland (Moreland, 1974), the maximum ground-water storage is estimated to be 92,000 acre-ft. Ground water is unconfined in the eastern part of the aquifer but may be confined in the western part.

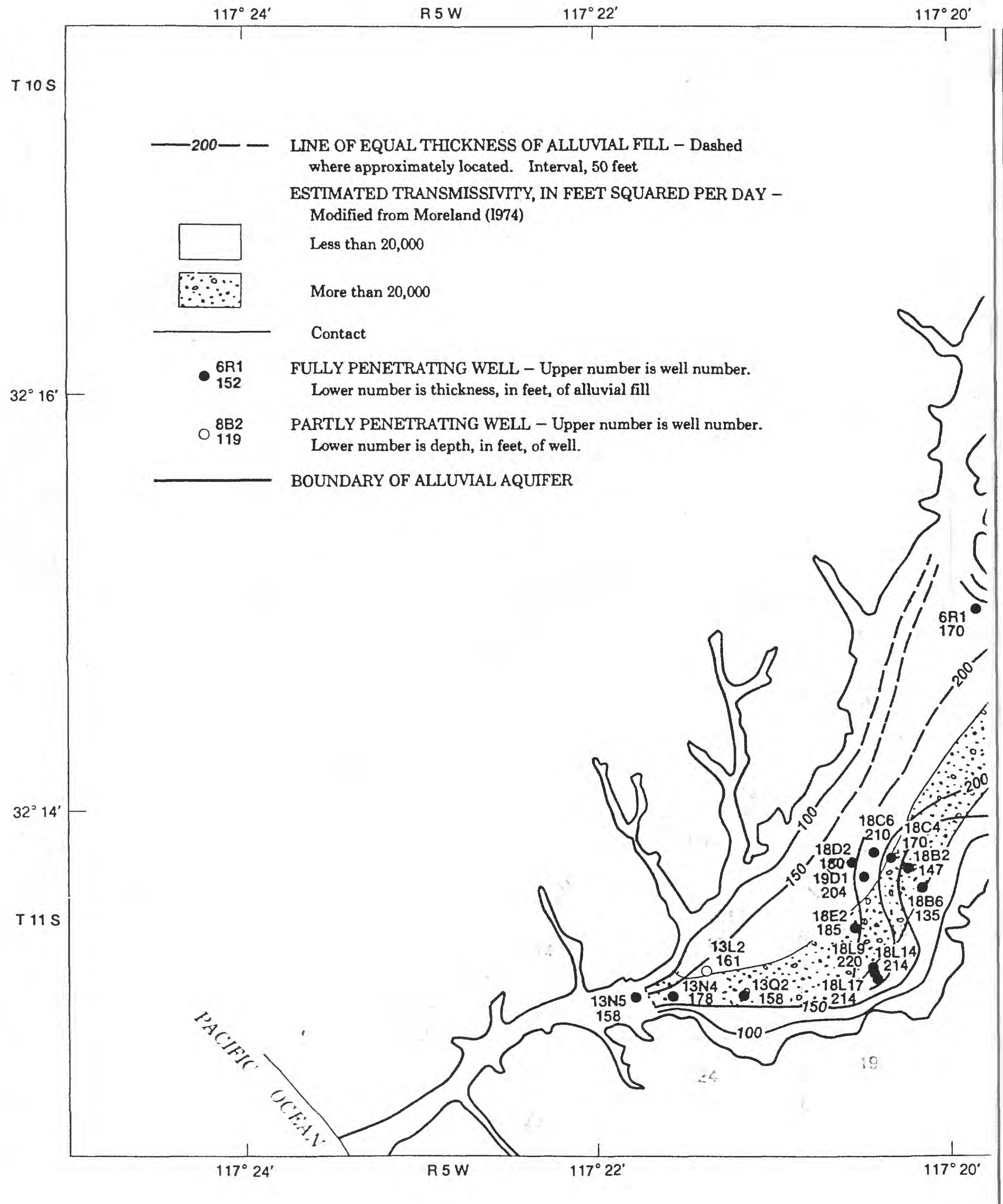
Drillers' information and previous work by Moyle (1971) indicate that well yields may exceed 2,000 gal/min, and average almost 500 gal/min. The most productive materials are sand and gravel in the eastern part of the aquifer and the coarse sand and gravel of buried river channels near the base of the aquifer in the western part. Silt and clay overlying the buried river channels confines ground water. The base of the alluvial fill is readily identified by hard, yellow sandstone typical of the La Jolla Group.

In the sands and gravels of the western part of the aquifer, specific capacities may be as much as 150 (gal/min)/ft of drawdown. In the remainder of the alluvial fill, specific capacities average 25 (gal/min)/ft of drawdown. Aquifer transmissivity was estimated by multiplying hydraulic conductivities calculated by Moreland (1974) by the aquifer thickness. Areas with transmissivities less than or greater than 20,000 ft^2/d are shown in figure 7.

The alluvial aquifer includes older alluvial fill (Pleistocene age) that underlies and surrounds younger alluvial fill (Holocene age) in the Mission subarea. The older alluvial fill, composed of gravel, sand, silt, and clay, has been partly cemented and weathered. Well yields, specific yields, specific capacities, and transmissivities are less in older alluvial fill than in younger alluvial fill. Hydraulic continuity is assumed between older and younger alluvial fill, and ground water probably moves freely between the two units. Because of greater land-surface elevation of the older alluvial fill, depth to water tends to be greater than in the younger alluvial fill.

Recharge.--Historically, the primary source of recharge to the alluvial aquifer was infiltration of streamflow from the San Luis Rey River. Recharge has been calculated as the difference between streamflow near Bonsall and at Oceanside (fig. 8). Between 1930 and 1969, recharge from the San Luis Rey River to the alluvial aquifer averaged 1,670 acre-ft per year. In 1937, recharge was 7,240 acre-ft. Lesser amounts of recharge also occurred as infiltration from Pilgrim Creek, as ground-water movement through the narrows near Bonsall, and as infiltration of precipitation.

After 1965, the alluvial aquifer was recharged by imported irrigation water in upland areas and by stormflow in the San Luis Rey River. By 1969, the aquifer had nearly filled and ground water was discharged to the San Luis Rey River.


117° 24'
R 5 W
117° 22'
117° 20'
T 10 S
T 11 S
32° 16'
32° 14'
200
LINE OF EQUAL THICKNESS OF ALLUVIAL FILL – Dashed where approximately located. Interval, 50 feet
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY – Modified from Moreland (1974)
Less than 20,000
More than 20,000
Contact
6R1
152
FULLY PENETRATING WELL – Upper number is well number. Lower number is thickness, in feet, of alluvial fill
8B2
119
PARTLY PENETRATING WELL – Upper number is well number. Lower number is depth, in feet, of well.
BOUNDARY OF ALLUVIAL AQUIFER
PACIFIC OCEAN
6R1
170
200
100
150
18C6
210
18C4
170
18D2
180
18B2
147
19D1
204
18B6
135
18E2
185
13L2
161
18L9
220
18L14
214
13N4
178
13Q2
158
18L17
214
13N5
158
19
24

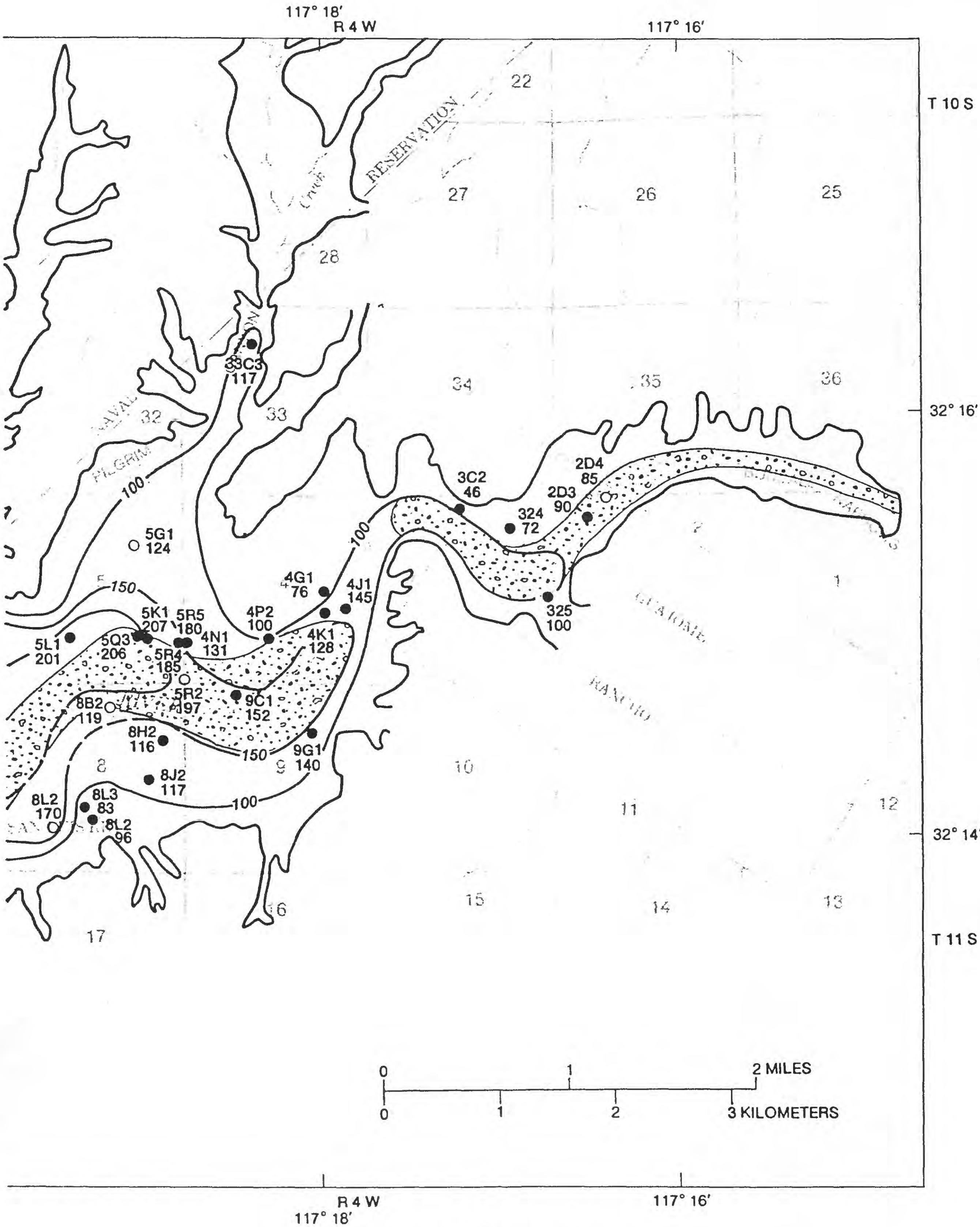


FIGURE 7. - Thickness of the Mission alluvial aquifer.

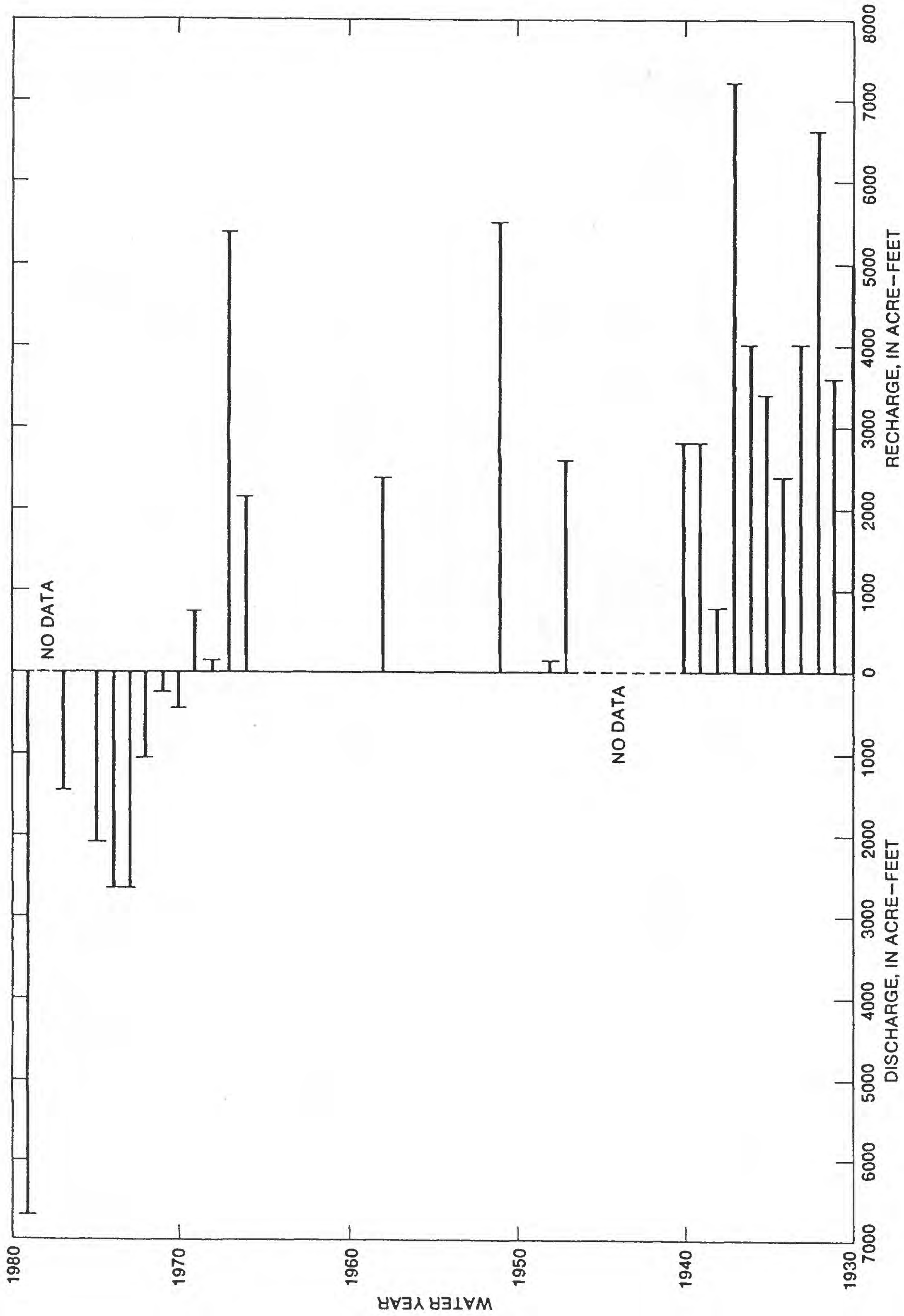


FIGURE 8. - Recharge to and discharge from the Mission alluvial aquifer from the San Luis Rey River.

Occurrence and movement.--Movement of ground water in the alluvial aquifer is from narrows near Bonsall downgradient to the Pacific Ocean.

Prior to ground-water development, water levels were within a few feet of land surface much of the year. After World War II, water levels in the alluvial aquifer began to decline (fig. 9). By the early 1950's, ground-water levels were below sea level in parts of the aquifer, and by 1956, water levels were as much as 43 feet below sea level (78 feet below land surface). A water-level-contour map of the alluvial aquifer in spring 1958 is shown in figure 10. It reflects the lowest water levels prior to the beginning of a pumping season. At that time, water levels were as much as 14 feet below sea level (49 feet below land surface), and seawater intrusion was moving through the narrow canyon that separated the main body of the alluvial aquifer from the Pacific Ocean. Water levels continued to decline in the eastern part of the aquifer until 1965. At that time, water levels were as much as 70 feet below land surface, and the alluvial aquifer in this area was virtually dry. By 1970, water levels in the alluvial fill had almost returned to predevelopment levels. Water levels in the alluvial aquifer during spring 1983 are shown in figure 11. Depth to water in wells generally ranged from above land surface to 20 feet below land surface.

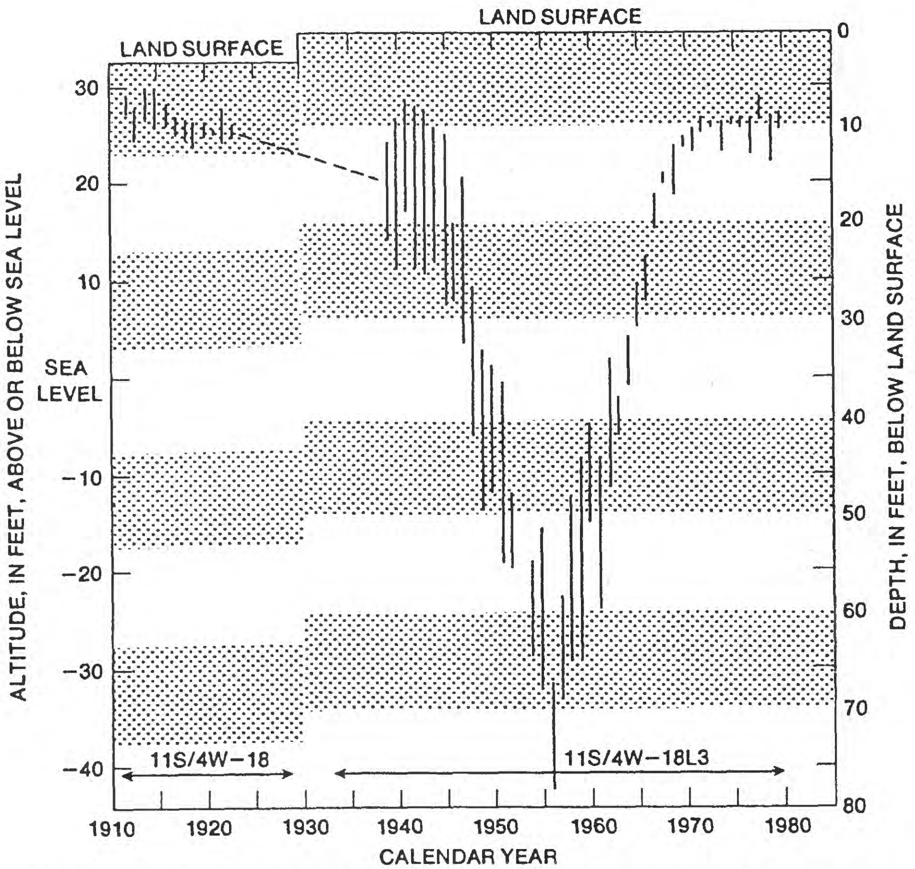
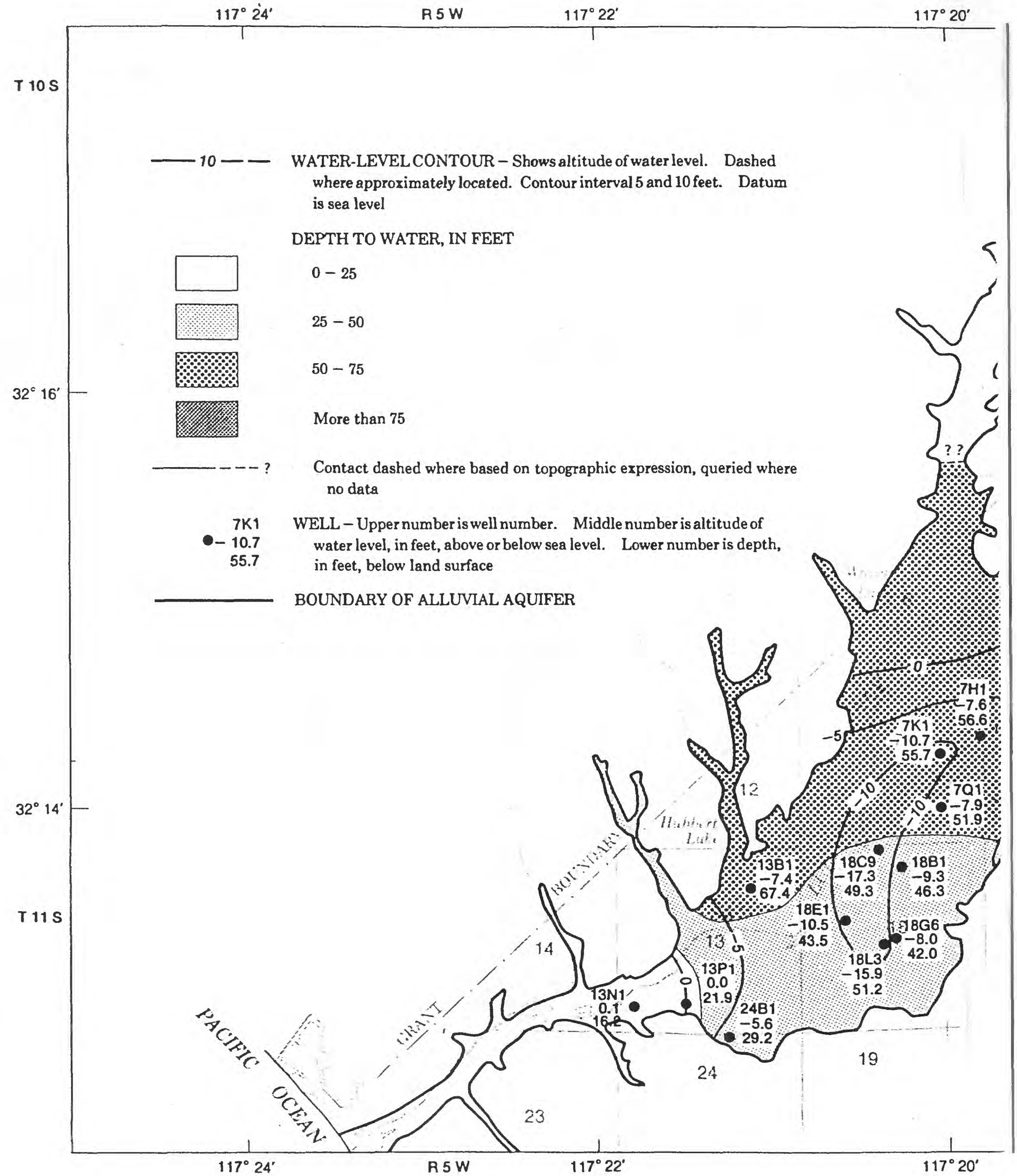


FIGURE 9. - Water levels for wells in the Mission alluvial aquifer. Vertical bar indicates range of water-level fluctuation during year. (Location of wells shown in figure 32.)


117° 24′
R 5 W
117° 22′
117° 20′
T 10 S
32° 16′
32° 14′
T 11 S
WATER-LEVEL CONTOUR – Shows altitude of water level. Dashed where approximately located. Contour interval 5 and 10 feet. Datum is sea level
10
DEPTH TO WATER, IN FEET
0 – 25
25 – 50
50 – 75
More than 75
Contact dashed where based on topographic expression, queried where no data
?
WELL – Upper number is well number. Middle number is altitude of water level, in feet, above or below sea level. Lower number is depth, in feet, below land surface
7K1
10.7
55.7
BOUNDARY OF ALLUVIAL AQUIFER
PACIFIC OCEAN
GRANT BOUNDARY
7H1
−7.6
56.6
7K1
−10.7
55.7
7Q1
−7.9
51.9
13B1
−7.4
67.4
18C9
−17.3
49.3
18B1
−9.3
46.3
18E1
−10.5
43.5
18G6
−8.0
42.0
18L3
−15.9
51.2
13P1
0.0
21.9
13N1
0.1
16.2
24B1
−5.6
29.2
0
−5
−10
12
13
14
19
23
24

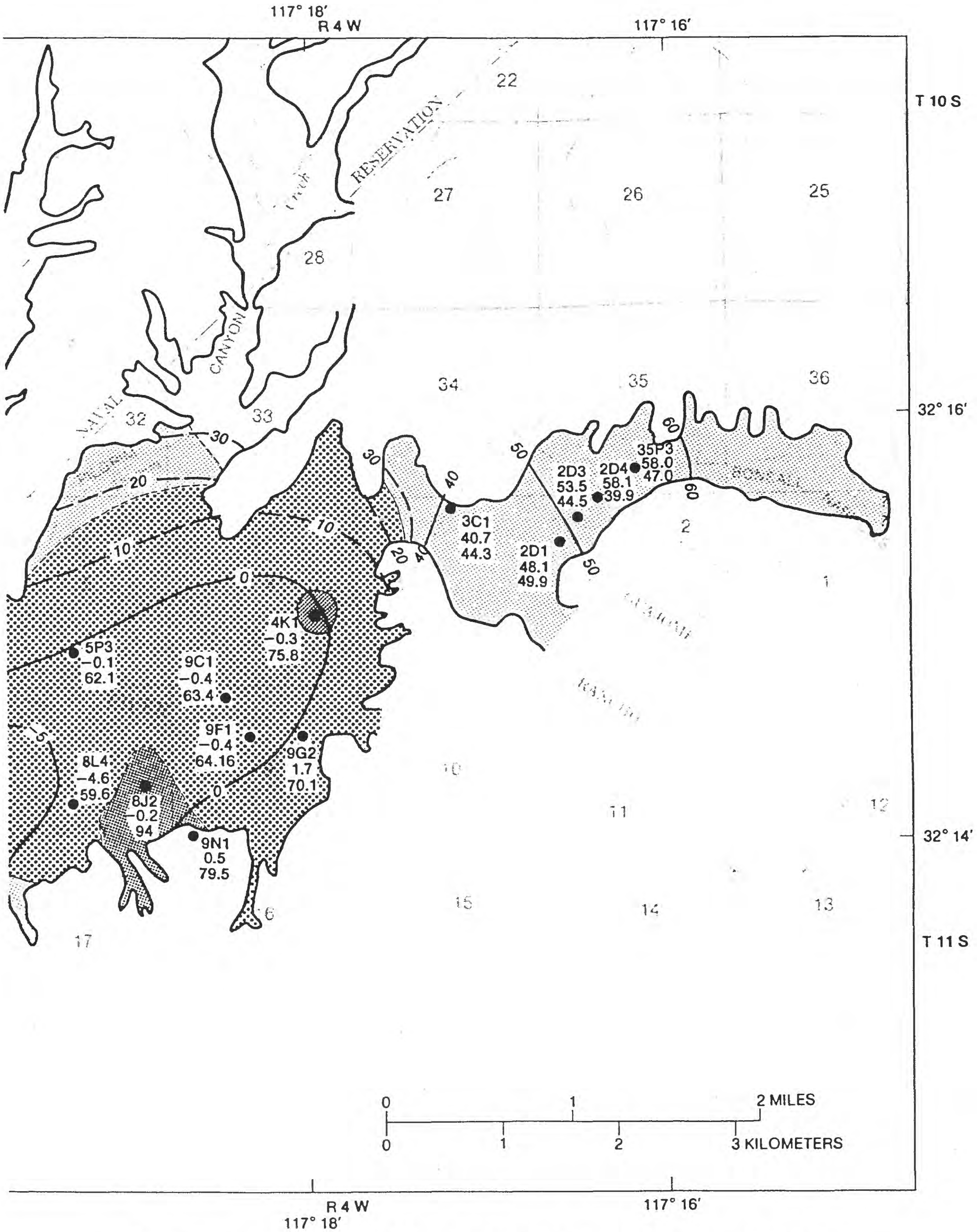
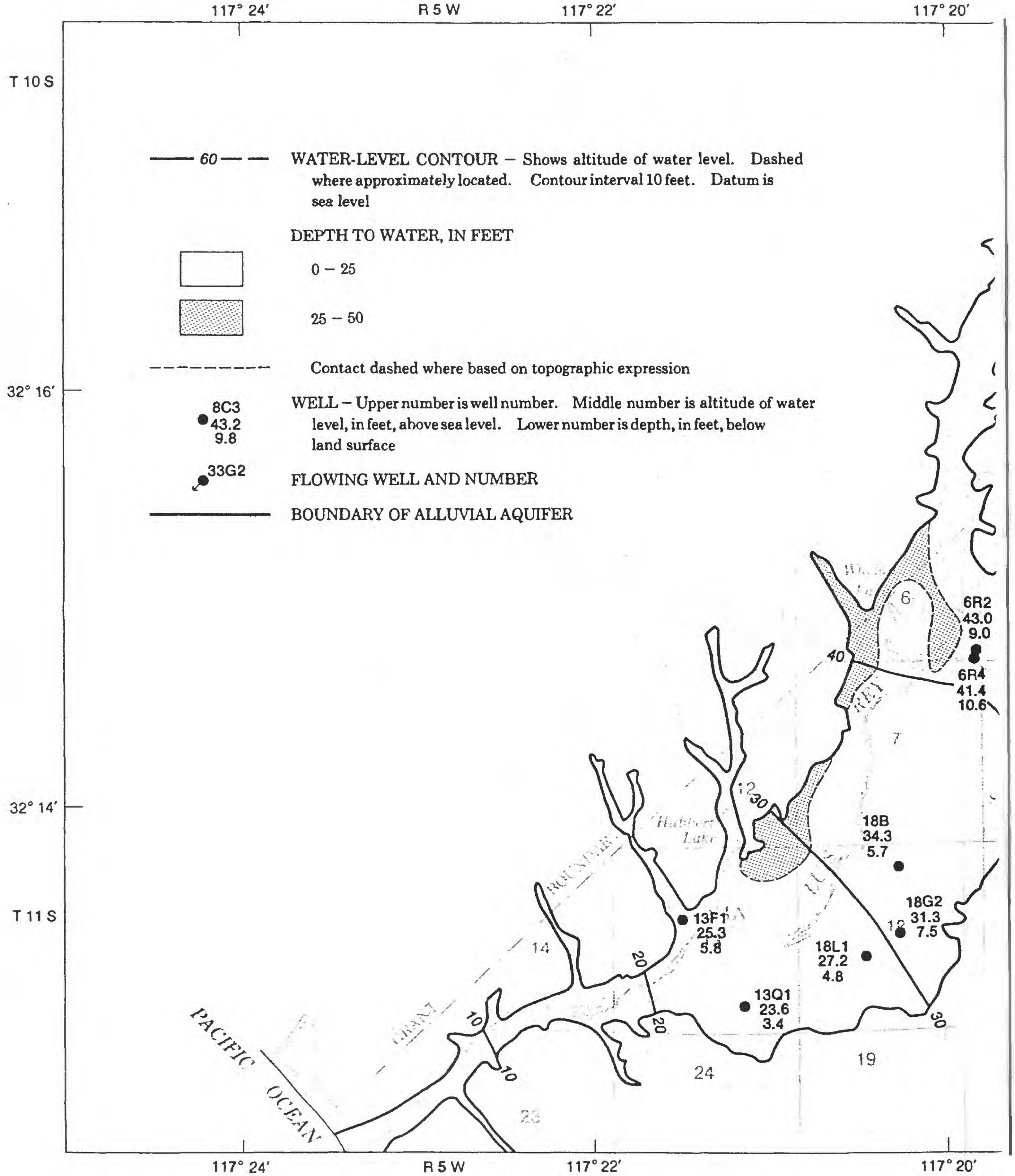


FIGURE 10. - Water-level contours and depth to water in the Mission alluvial aquifer, spring 1958.


117° 24'
R 5 W
117° 22'
117° 20'
T 10 S
32° 16'
32° 14'
T 11 S
60
WATER-LEVEL CONTOUR – Shows altitude of water level. Dashed where approximately located. Contour interval 10 feet. Datum is sea level
DEPTH TO WATER, IN FEET
0 – 25
25 – 50
Contact dashed where based on topographic expression
8C3
43.2
9.8
WELL – Upper number is well number. Middle number is altitude of water level, in feet, above sea level. Lower number is depth, in feet, below land surface
33G2
FLOWING WELL AND NUMBER
BOUNDARY OF ALLUVIAL AQUIFER
6R2
43.0
9.0
6R4
41.4
10.6
40
6
7
30
18B
34.3
5.7
18G2
31.3
7.5
13F1
25.3
5.8
18L1
27.2
4.8
13Q1
23.6
3.4
20
10
14
19
24
PACIFIC
OCEAN

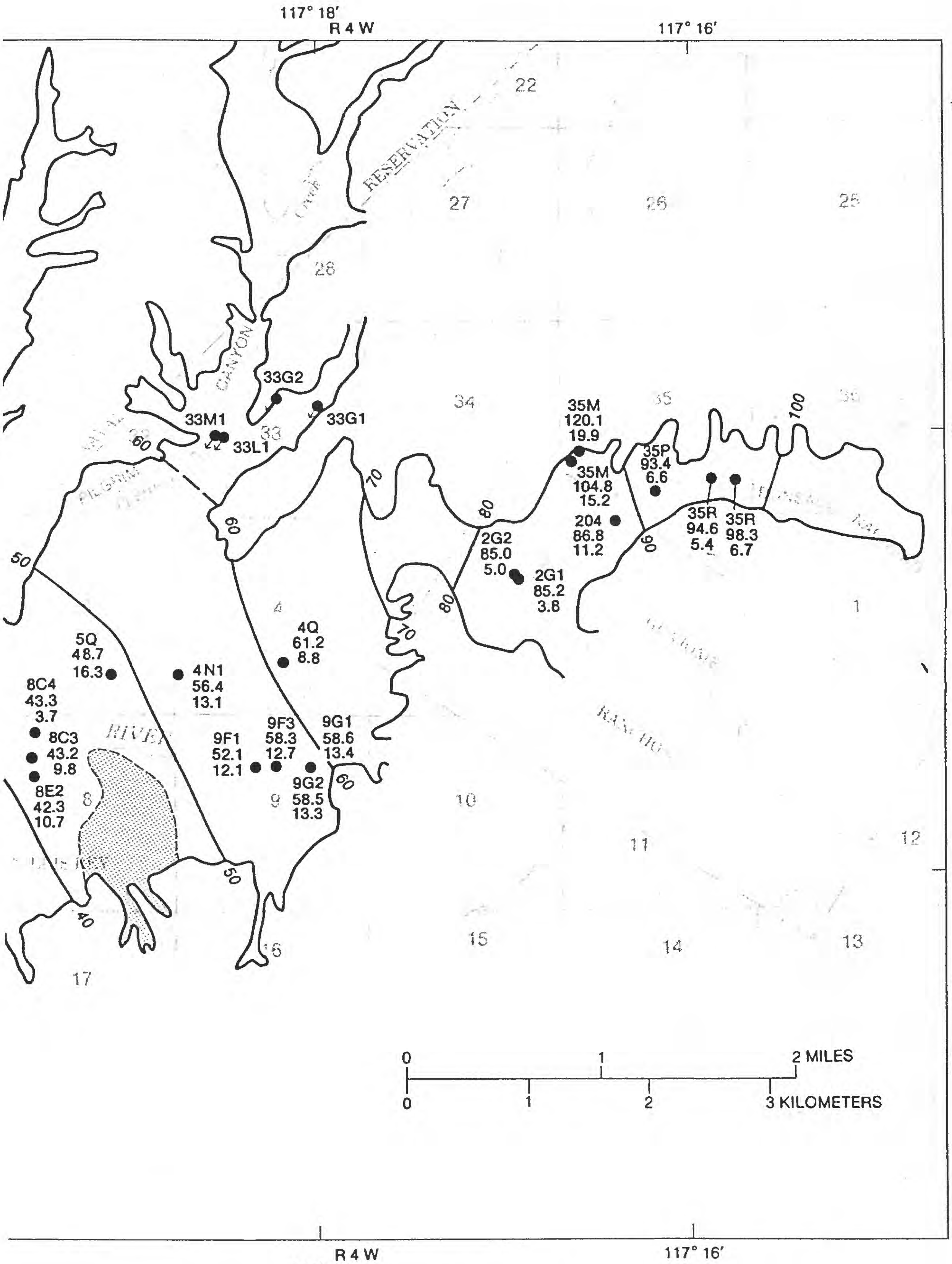


FIGURE 11. - Water-level contours and depth to water in the Mission alluvial aquifer, spring 1983.

Ground-Water Quality

Quality of ground water within the Mission hydrologic subarea varies with the geologic formation from which it is obtained. Differences in ground-water chemistry have been discussed using water-quality types. Water-quality types (or simply water types) are named on the basis of the predominant cation and anion in milliequivalents per liter. For example, a sodium chloride water type is one in which at least 50 percent of the cations are sodium and at least 50 percent of the anions are chloride; a mixed cation chloride water type is one in which there is no predominant cation and 50 percent of the anions are chloride; a mixed water type is one in which no ion exceeds 50 percent of the total anions or cations in milliequivalents per liter. Typical ground-water quality in each geologic formation is summarized in table 5.

Peninsular Range Province

Prior to large-scale use of imported water for irrigation in the Mission subarea, dissolved-solids concentrations of ground-water samples from wells in crystalline rocks ranged from 560 to 740 mg/L; median concentration was 630 mg/L. Water type was mixed cation chloride. Sulfate was of minor importance.

In spring 1983, three wells yielding water from crystalline rocks were sampled. Water type was similar to earlier analysis; however, in at least one well, sulfate was a major constituent. Dissolved solids ranged from 1,020 to 1,760 mg/L. Chloride exceeded U.S. Environmental Protection Agency (1976) recommended limits for drinking water of 250 mg/L in all three wells. Sulfate and nitrate exceeded recommended limits of 250 mg/L and 10 mg/L as nitrogen in at least one well sampled (table 14 at end of report).

Changes in water quality over time are most likely related to increases in irrigation-return water recharging the ground water.

Pacific Coastal Plain

Historically, dissolved-solids concentration of water from wells in the Mission subarea in the La Jolla Group

TABLE 5.--Water quality of aquifers in the Mission hydrologic subarea

[--, no data. Abbreviation: mg/L, milligrams per liter]

Geologic unit	Map symbol (see pl. 1)	Exposure in subarea (acres)	Typical dissolved solids	Typical water type	Water-quality problems
Alluvium	Qal	9,800	Between 960 and 3,090 mg/L; median 1,200 mg/L.	Mixed type to sodium chloride near the ocean.	Dissolved solids, chloride, and sulfate.
Unnamed marine terrace deposits	Qt	1,950	--	--	--
San Onofre Breccia	Tso	750	--	--	--
La Jolla Group	Tlj	7,000	Between 1,140 and 2,390 mg/L; median 1,680 mg/L.	Mixed type to sodium chloride with increasing well depth.	Dissolved solids, chloride.
Crystalline rocks	Kt, KJsp	11,000	As much as 1,760 mg/L.	Mixed cation chloride.	Dissolved solids, sulfate, and nitrate.

ranged from 1,140 to 2,390 mg/L; median concentration was 1,680 mg/L. Deep wells in the La Jolla Group yielded a sodium chloride type water; shallower wells, because of leaching of sodium chloride salts by infiltrating precipitation, yielded a mixed type water (Izbicki, 1983). Sulfate and chloride exceeded the U.S. Environmental Protection Agency (1979) recommended limit for drinking water of 250 mg/L in all wells sampled. In areas where other supplies are unavailable, the La Jolla Group provides water for washing, cleaning, fire protection, and irrigation of salt-tolerant plants. Wells yielding water from the La Jolla Group were not sampled in autumn 1982 or spring 1983.

Alluvial Aquifer

Historical water quality.--The earliest available ground-water-quality data for the Mission subarea were collected by Ellis and Lee (1919) in March 1918. At that time, a well in section 11S/5W-13N yielded water with a dissolved-solids concentration of 450 mg/L. By the late 1930's, the community of Oceanside began to develop the Mission alluvial aquifer as a municipal drinking-water supply and began monitoring ground-water quality. Changes in dissolved-solids concentrations of ground water, with time, are shown as semilogarithmic plots in figure 12.

In the western parts of the aquifer, dissolved-solids concentrations of ground water began to increase as early as the mid-1940's in response to seawater intrusion. In the western part of the Mission alluvial aquifer, the effect of seawater intrusion was greatest in well 11S/5W-23E1, nearest the ocean, intermediate in well 11S/5W-13Q1, and least in well 11S/4W-18L3, farthest (of the three) from the ocean.

By 1965, changes in the flow characteristics of the San Luis Rey River were occurring as a result of agricultural return from irrigation with imported water, and increases in ground-water recharge were beginning to affect ground-water quality. In the eastern parts of the aquifer where wells had not been affected by seawater intrusion, the dissolved-solids concentration of ground water began to increase. In the western parts of the aquifer where wells had been affected by seawater intrusion, the dissolved-solids concentration of ground water began to decrease. Large-scale use of imported water for irrigation in uplands of the lower San Luis Rey River valley reversed water-quality trends caused by seawater intrusion, but as a consequence the aquifer filled with irrigation-return water.

Present water quality.--In autumn 1982 and spring 1983, water in the alluvial aquifer was primarily a mixed type (fig. 13). However, well 11S/5W-13F1, nearest the Pacific Ocean, yielded a sodium chloride type water and probably reflects seawater intrusion.

Field measurements of specific conductance were converted to dissolved solids using the following relation:

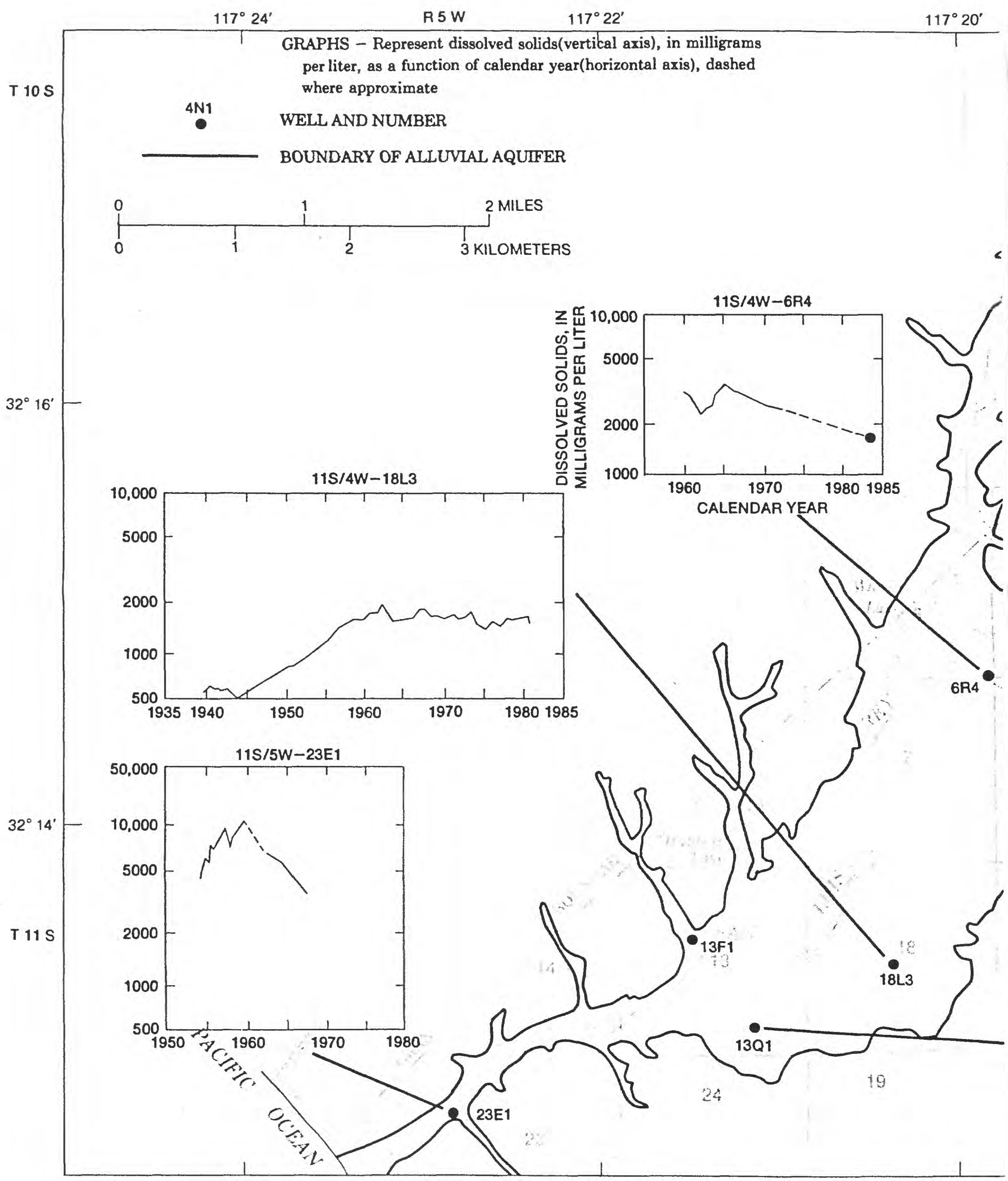
$$DS = 0.51\ SC + 234$$

where

DS is dissolved-solids concentration, in milligrams per liter; and

SC is specific conductance, in micromhos per centimeter at 25°C.

This relation was developed with data collected by the U.S. Geological Survey between autumn 1982 and spring 1983, using linear regression. Twelve samples with dissolved-solids concentrations ranging from 1,020 to 1,760 mg/L were used and an R^2 of 0.86 was obtained. (R^2 is a statistic which describes the "goodness of fit" of data about a line. It may range from 0 for a very poor fit to 1 for a perfect fit.) The data base included analyses from wells in the Mission subarea but outside the alluvial aquifer. This relation is basin specific and care should be used when extrapolating to other areas.


117° 24'
R 5 W
117° 22'
117° 20'
T 10 S
T 11 S
32° 16'
32° 14'
GRAPHS – Represent dissolved solids(vertical axis), in milligrams per liter, as a function of calendar year(horizontal axis), dashed where approximate
4N1
WELL AND NUMBER
BOUNDARY OF ALLUVIAL AQUIFER
0 1 2 MILES
0 1 2 3 KILOMETERS
11S/4W–6R4
DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER
10,000
5000
2000
1000
1960 1970 1980 1985
CALENDAR YEAR
11S/4W–18L3
10,000
5000
2000
1000
500
1935 1940 1950 1960 1970 1980 1985
11S/5W–23E1
50,000
10,000
5000
2000
1000
500
1950 1960 1970 1980
PACIFIC OCEAN
6R4
13F1
18L3
13Q1
23E1
13
14
18
19
24

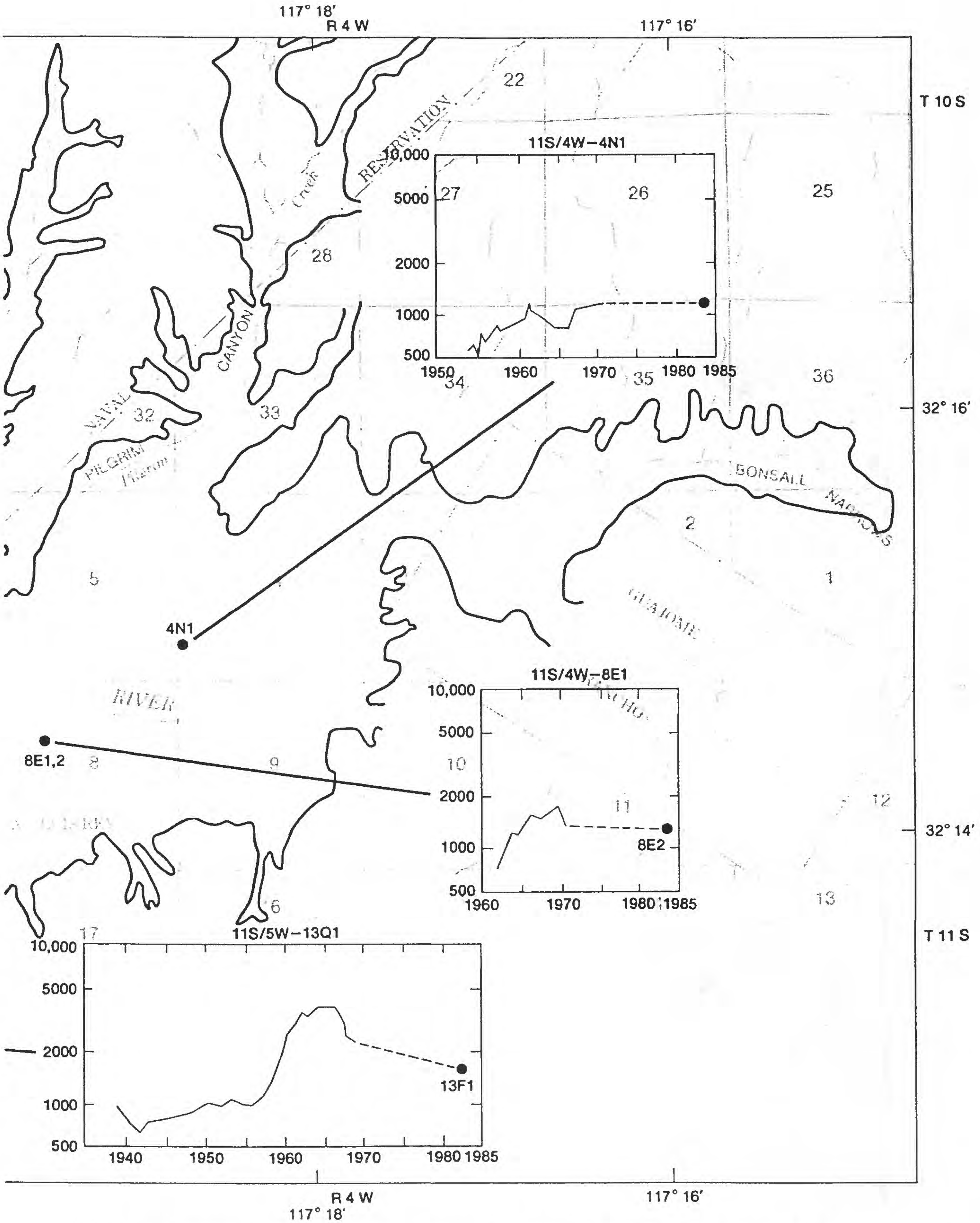
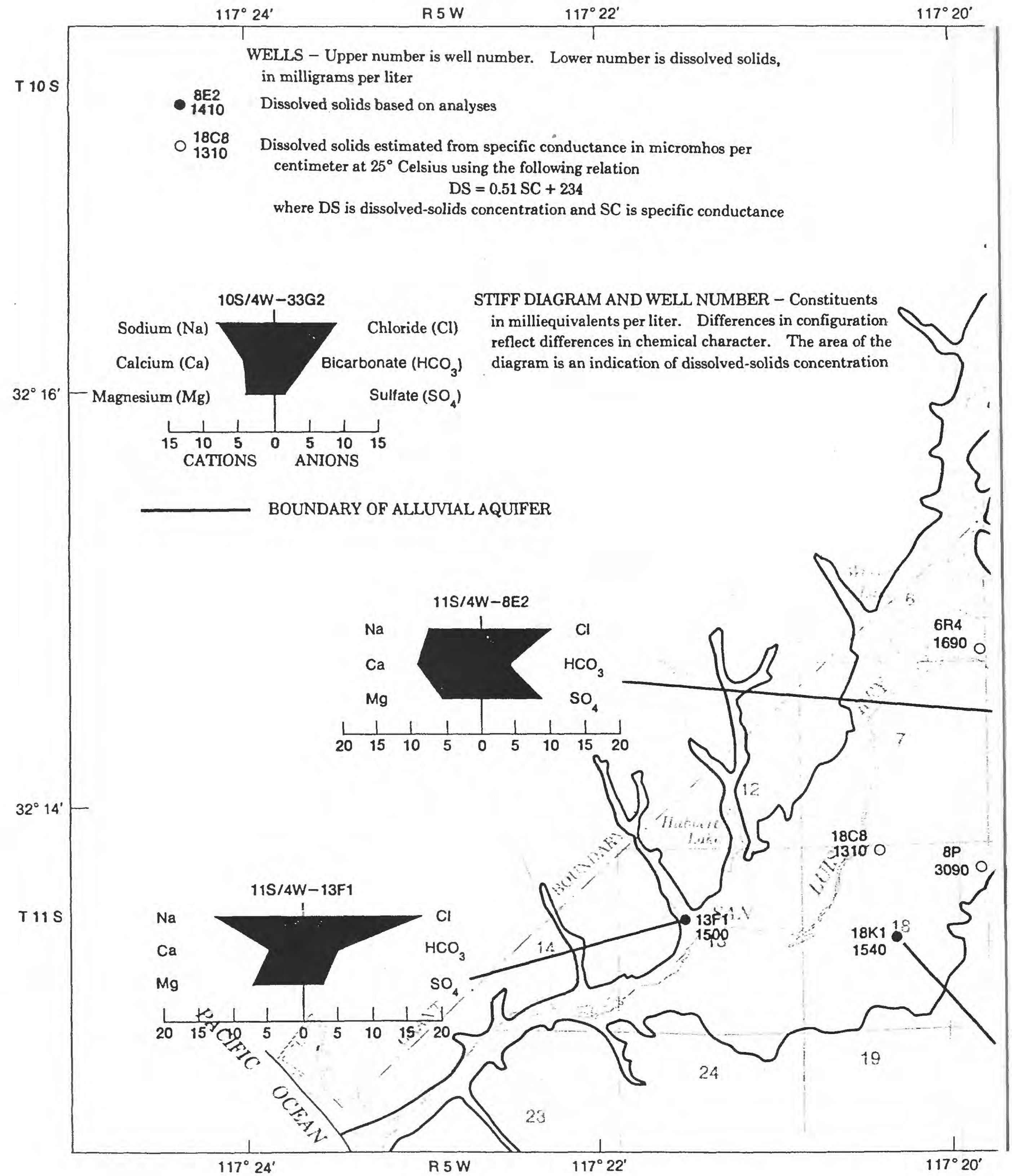


FIGURE 12. - Changes in dissolved-solids concentrations with time at selected wells in the Mission alluvial aquifer.


117° 24'
R 5 W
117° 22'
117° 20'
T 10 S
WELLS – Upper number is well number. Lower number is dissolved solids, in milligrams per liter
8E2
1410
Dissolved solids based on analyses
18C8
1310
Dissolved solids estimated from specific conductance in micromhos per centimeter at 25° Celsius using the following relation
DS = 0.51 SC + 234
where DS is dissolved-solids concentration and SC is specific conductance
10S/4W–33G2
Sodium (Na)
Calcium (Ca)
Magnesium (Mg)
Chloride (Cl)
Bicarbonate (HCO_3)
Sulfate (SO_4)
15 10 5 0 5 10 15
CATIONS ANIONS
STIFF DIAGRAM AND WELL NUMBER – Constituents in milliequivalents per liter. Differences in configuration reflect differences in chemical character. The area of the diagram is an indication of dissolved-solids concentration
32° 16'
BOUNDARY OF ALLUVIAL AQUIFER
11S/4W–8E2
Na
Ca
Mg
Cl
HCO_3
SO_4
20 15 10 5 0 5 10 15 20
6R4
1690
7
12
32° 14'
18C8
1310
8P
3090
11S/4W–13F1
T 11 S
Na
Ca
Mg
Cl
HCO_3
SO_4
20 15 10 5 0 5 10 15 20
13F1
1500
18K1
1540
14
24
19
23
PACIFIC
OCEAN
117° 24'
R 5 W
117° 22'
117° 20'

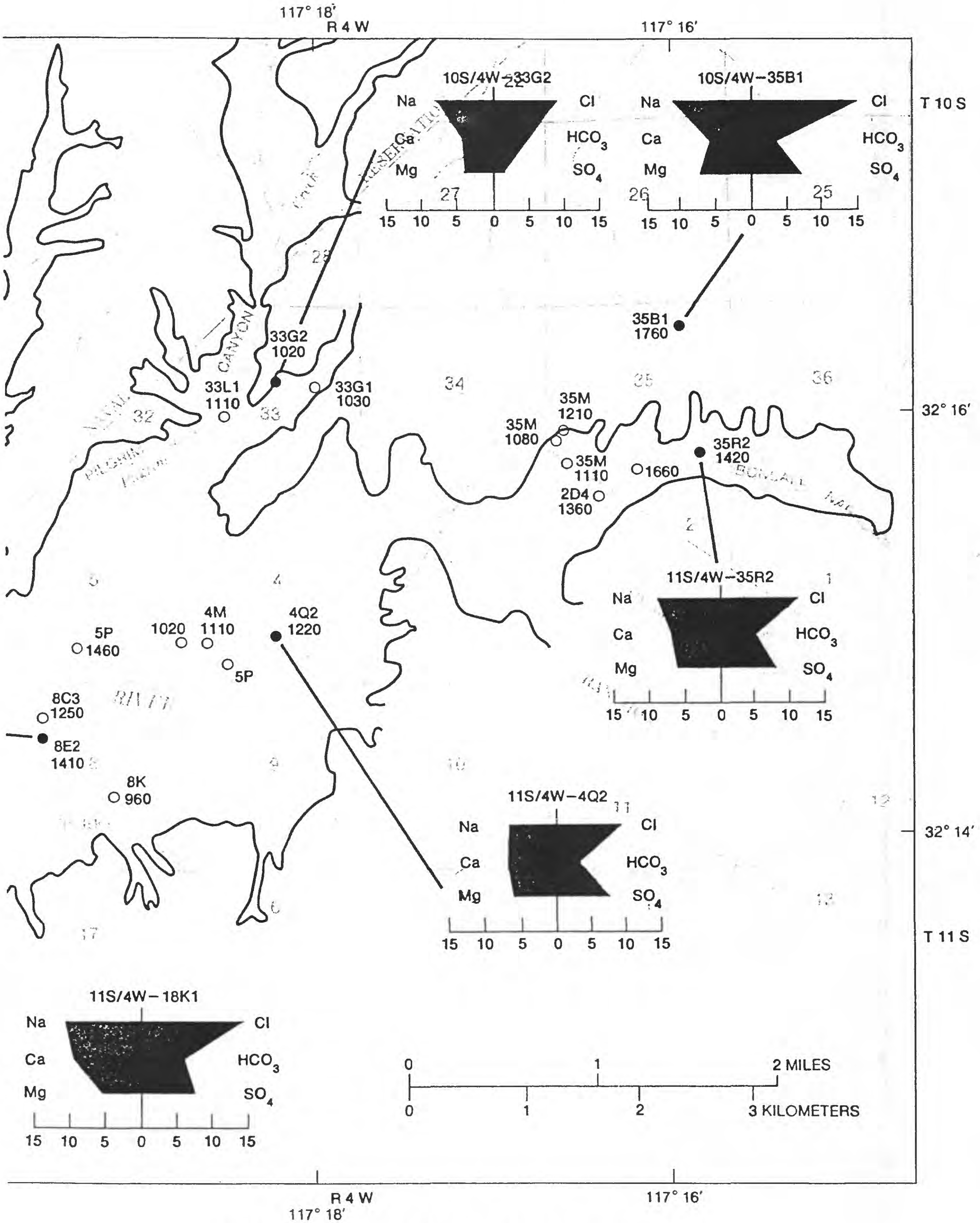


FIGURE 13. - Water quality in the Mission alluvial aquifer, spring 1983.

Dissolved-solids concentrations in spring 1983 ranged from 960 to 3,090 mg/L. Four of twenty-two wells sampled yielded water with a dissolved-solids concentration exceeding the basin objective of 1,500 mg/L. Only one well, 11S/4W-8K1, yielded water with a dissolved-solids concentration less than 1,000 mg/L. This well yielded water from the older alluvial fill (Pleistocene age).

Reclaimed-Water Use

At present (1984), reclaimed-water-management plans have not been developed for the Mission subarea. Although actual effects will depend greatly on the reclaimed-water-management plan ultimately adopted, it is possible to make general statements concerning the effects of reclaimed-water use on water quality and quantity. To be properly evaluated, effects should be compared to and contrasted with possible future trends in water quality and quantity.

Changes in natural recharge caused by large-scale use of imported water for irrigation have altered ground-water quality. Water-quality problems associated with dissolved solids greater than 1,000 mg/L, chloride greater than 250 mg/L, and, in some wells, sulfate greater than 250 mg/L, limit the uses of ground water in the Mission subarea. Currently, ground-water levels are at or near land surface throughout much of the alluvial aquifer. Some wells and springs flow year round with irrigation-return water. The quantity of additional recharge has been great enough to transform the Mission subarea into a water-yielding area, which discharges significant quantities of water to the San Luis Rey River. As long as large-scale use of imported water for irrigation persists in upland areas of the Mission subarea, and in the remainder of the San Luis Rey River valley, present water quality and hydrologic conditions will continue.

Reclaimed-Water Quality

Reclaimed water used in this subarea would be secondary-treated sewage effluent from the Oceanside Wastewater Treatment Plant. In 11 analyses collected by the city of Oceanside Water and Sewer Department (Gus Pennell, written commun., 1983) between January 20, 1982, and February 9, 1983, reclaimed water had smaller concentrations of dissolved solids, chloride, and sulfate than existing ground-water supplies. Although nitrate in reclaimed water is low, nitrification of ammonia could result in nitrate as nitrogen in ground water exceeding 10 mg/L. Dissolved solids, chloride, and percent sodium are occasionally high enough to adversely affect certain sensitive plants (U.S. Department of Agriculture, 1954). The U.S. Geological Survey analyzed a 24-hour composite sample collected March 13-14, 1983, by personnel from the city of Oceanside Water and Sewer Department. With the exception of higher pH and alkalinity, the results are comparable with data from the city of Oceanside (table 6). Complete analyses are summarized in tables 14-15 at the end of report.

Effects of Reclaimed-Water Use

If reclaimed water is used for irrigation in upland areas as a replacement for imported water, hydrologic conditions outlined in this report (high ground-water levels, flowing wells and springs, and year-round flow in the San Luis Rey River) will continue. In some areas, if reclaimed water is to have adequate soil contact before discharging at land surface, special irrigation techniques and limited application rates may be required. Application rates, volumes, and techniques will have to be evaluated on a site-specific basis. If reclaimed water is used solely as a replacement for irrigation with imported water, ground and surface-water quality is likely to deteriorate with respect to dissolved solids, chloride, sulfate, and other dissolved constituents. The degree of

TABLE 6.--Reclaimed-water quality, Mission hydrologic subarea

[Specific conductance, in micromhos per centimeter at 25°C; pH, in units; constituents, in milligrams per liter. --, no data]

Source of data	Sampling period		Specific conductance	pH	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Alkalinity as $CaCO_3$	Sulfate, dissolved	Chloride, dissolved	Dissolved solids	Nitrate as N	Ammonia as N
City of Oceanside, Wastewater Treatment Plant, Water and Sewer Department	January 20, 1982 to February 9, 1983	Minimum	--	7.2	--	--	160	12	172	190	200	843	--	10
		Median	--	7.4	--	--	190	16	220	240	240	983	--	16
		Maximum	--	7.6	--	--	220	19	278	280	280	1,050	--	34
		Number of samples	--	8	--	--	11	11	11	11	11	11	--	11
U.S. Geological Survey	24-hour composite 7 a.m. March 13, 1983 to 7 a.m. March 14, 1983		1,410	7.8	73	35	210	12	280	220	260	980	1.7	21

change will be proportional to the difference in quality between present irrigation supplies and the reclaimed water.

Plans aimed at improving ground-water quality by pumping ground water from the subarea and replacing it with reclaimed water having dissolved-solids concentrations ranging from 843 to 1,050 mg/L may not be feasible because of the possibility of increased infiltration of high dissolved-solids water from the San Luis Rey River, particularly during base flows. However, conjunctive use of ground water, reclaimed water, and high-quality stormflow water in the San Luis Rey River may improve ground-water quality and promote beneficial use of existing water resources.

SANTEE HYDROLOGIC SUBAREA

Geology

The Santee hydrologic subarea is divided into two distinct physiographic zones; the eastern part lies within the Peninsular Range Province and the western within the Pacific Coastal Plain (pl. 3).

Peninsular Range Province

The eastern part of the Santee subarea is within the Peninsular Range Province. Crystalline rocks--primarily granodiorite, tonalite, and small bodies of metamorphic rocks--are exposed in or underlie this area. Granodiorites are resistant to erosion and form prominent peaks and cliffs at El Cajon Mountain. Tonalite is more easily weathered and erodes to form rolling, hilly topography. Tonalite may weather to several hundred feet in depth, forming a material known locally as residuum or decomposed granite.

Granitic and volcanic rocks also form the western boundary of the Santee subarea at Cowles Mountain.

Pacific Coastal Plain

The western part of the Santee subarea is within the Pacific Coastal Plain and is underlain by partly consolidated continental and marine conglomerate of the Eocene Poway Group. This is the highest of the stairstep mesas of the San Diego area, and it has been incised by many small streams. Maximum thickness of the Poway Group is 1,000 feet (California Department of Water Resources, 1967a). Alluvial deposits occupy the long, narrow southwesterly trending valley of the San Diego River.

Soils

On the basis of topographic expression and geologic parent material, six soil associations have been identified in the Santee subarea (pl. 4): Rock-Land, Cienba-Fallbrook and Friant-Escondido, Fallbrook-Vista, Ramona-Placentia, Redding-Olivenhain and Diablo-Linne, and Visalia-Tujunga. The discussion which follows is based on work by the U.S. Soil Conservation Service (1973).

The Rock-Land association has developed over exposed granodiorite. Soil occurs in pockets between rock outcrops and very large boulders. Infiltration is primarily through cracks and fissures with only limited soil contact. The potential for surface runoff is very great.

The Cienba-Fallbrook association has also developed over granodiorite and is characterized by thin (less than 1.5 feet thick) Cienba soils and small areas of thicker (1.5 to 5 feet) Fallbrook soils. Infiltration rates are high to moderate throughout most of the association, ranging from 20 in/h for Cienba soils to 0.06 to 2.0 in/h for Fallbrook soils. Although soil development has been much greater than in the Rock-Land association, large boulders and areas of exposed bedrock are common.

Included within the Cienba-Fallbrook map unit is the Friant-Escondido association. Soils of the Friant-Escondido association developed over metasedimentary and metavolcanic rocks. Thin (less than 1.5 feet thick) Friant soils predominate, and only small areas of thicker (1.5 to 3 feet) Escondido soils are within the Santee subarea. Infiltration rates are high for Friant soils (between 2.0 to 6.3 in/h) and moderate for Escondido soils (0.63 to 2.0 in/h).

The Fallbrook-Vista association has developed over tonalite and contains soils typical of the Cienba-Fallbrook association, but in different proportions. Fallbrook and Vista soils, 1.5 to 5 feet thick, are next to thin Cienba soils included in this association. Infiltration rates are moderate for Fallbrook soils and high (2.0 to 6.3 in/h) for Vista soils. Small areas of thick Ramona soils with poor infiltration rates are included in this association.

The Ramona-Placentia association has developed over tonalite, weathered tonalite, and alluvial fill derived primarily from weathered tonalite. The association is characterized by soils which routinely attain thicknesses greater than 5 feet. Clay hardpans are common; consequently, infiltration rates are low, ranging from less than 0.06 in/h for Placentia soils to 0.2 to 0.63 in/h for Ramona soils. Parts of the soil profile with less clay may have higher infiltration rates.

Redding-Olivenhain and Diablo-Linne soils have developed over sedimentary rocks of the Pacific Coastal Plain. The associations are characterized by moderately thick (1 to 3.5 feet) Redding, Diablo, and Linne soils to thick (greater than 5 feet) Olivenhain soils. Redding, Olivenhain, and Diablo soils contain clay hardpans, with infiltration rates ranging from less than 0.06 to 0.2 in/h. Linne soils also contain appreciable amounts of clay and have infiltration rates of 0.2 to 0.63 in/h.

The Visalia-Tujunga association has developed on the alluvial valley floor and is characterized by thick (greater than 5 feet), sandy soils. Infiltration rates range from 2.0 to 6.3 in/h for Gaviota soils to greater than 20 in/h for Tujunga soils. As a group, these soils have the highest infiltration rates in the Santee subarea. The primary limitation on application of reclaimed water is a high water table, often within several feet of land surface much of the year.

Surface Water

Streamflow Characteristics

Streamflow into the Santee subarea is from the San Diego River, San Vicente Creek, and Forester Creek. A small quantity of streamflow originates within the Santee subarea. All surface flow leaves the subarea through the San Diego River at Mission Gorge. Location of gaging stations is shown in figure 14, and discharge data are summarized in table 7.

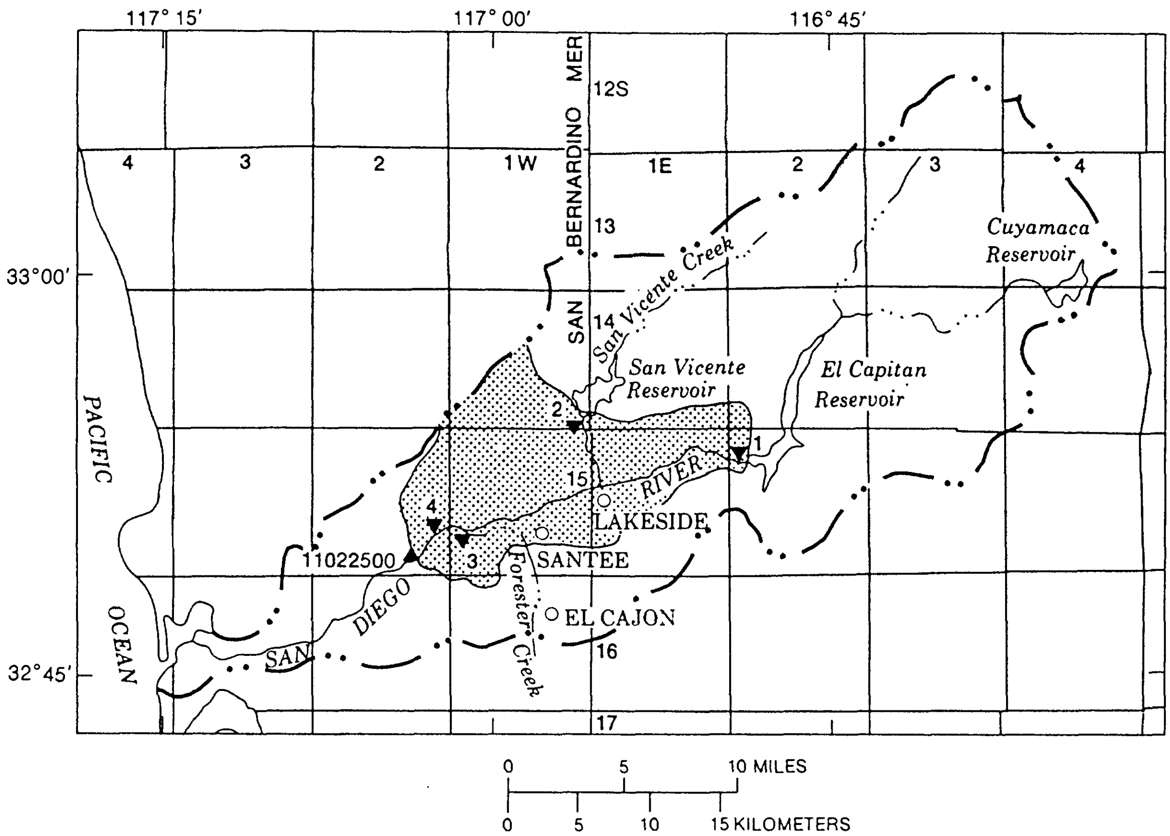
The San Diego River upstream from the Santee subarea drains a 188 mi^2 drainage basin. The basin is largely undeveloped and much of the area consists of national forest, state park, and Indian reservation lands. Flow in the river is regulated by Cuyamaca (capacity 11,500 acre-ft) and El Capitan (capacity 113,000 acre-ft) Reservoirs. Since construction of El Capitan Reservoir, streamflow occurs only as spills, releases, and leakage from the dam. Spill occurred in 1937, 1941, and 1980, and significant quantities of water were released in 1938, 1939, and 1983

TABLE 7. - Summary of discharge data for the Santee hydrologic subarea

[--, no data]

Station name	Station No.	Period of record	Drainage area (mi^2)	Annual discharge (acre-ft)		Median number of days with discharge greater than 0.1 ft^3/s	Maximum discharge for period of record	
				average	median		instantaneous (ft^3/s)	annual (acre-ft)
San Diego River; runoff into El Capitan Reservoir[1]	--	October 1934 to September 1974 October 1977 to September 1982	188	31,000	10,100	--	--	160,000
San Diego River; spill from El Capitan Reservoir[1,2,3]	--	October 1934 to May 1983	188	--	--	--	--	116,000
San Vicente Creek; runoff into San Vicente Reservoir[1]	--	October 1942 to September 1982	74	6,570	2,220	--	--	64,900
San Vicente Creek; spill from San Vicente Reservoir[1,4]	--	October 1942 to May 1983	74	--	--	--	--	32,100
San Diego River near Santee[2,3,4]	11022500	May 1912 to December 1915 March 1916 to September 1981	377	18,000	4,300	278	[5]70,200	159,000

[1]Data from city of San Diego Water Utilities Department.
[2]Flow regulated by Cuyamaca Reservoir, capacity 11,500 acre-ft.
[3]Flow regulated by El Capitan Reservoir, capacity 113,000 acre-ft.
[4]Flow regulated by San Vicente Reservoir, capacity 90,200 acre-ft.
[5]Miscellaneous measurement on January 27, 1916.



EXPLANATION

11022500 ▲ GAGING STATION AND NUMBER – See table 7 for discharge data

▼1 SURFACE-WATER-QUALITY SAMPLING STATIONS – Data on releases, spills, leakage, and runoff into El Capitan and San Vicente Reservoirs are available from City of San Diego Water Utilities Department

1 San Diego River below El Capitan Reservoir
2 San Vicente Creek below San Vicente Reservoir
3 Forester Creek at Mission Gorge Road, near Santee
4 San Diego River at Old Mission Dam, near Santee (11022490)

HYDROLOGIC SUBAREA

BOUNDARY OF DRAINAGE BASIN

FIGURE 14. - Location of gaging station and surface-water-quality sampling stations in the Santee hydrologic subarea.

(fig. 15). In other years, flow in the San Diego River was limited to leakage from the dam. From 1935-74, leakage varied with reservoir water level, but averaged almost 140 acre-ft/yr (unpublished data, city of San Diego Water Utilities Department). Recent data collected by the city of San Diego Water Utilities Department indicate leakage may be slightly greater (M. Sammak, city of San Diego Water Utilities Department, oral commun., 1983). Flow into the reservoir is estimated as the residual of other elements in the water budget of the reservoir and represents annual flow in the San Diego River below El Capitan Reservoir if the dam had not been built (G. Lesher, city of San Diego Water Utilities Department, oral commun., 1983). Median annual discharge into El Capitan Reservoir is approximately 10,100 acre-ft (fig. 15).

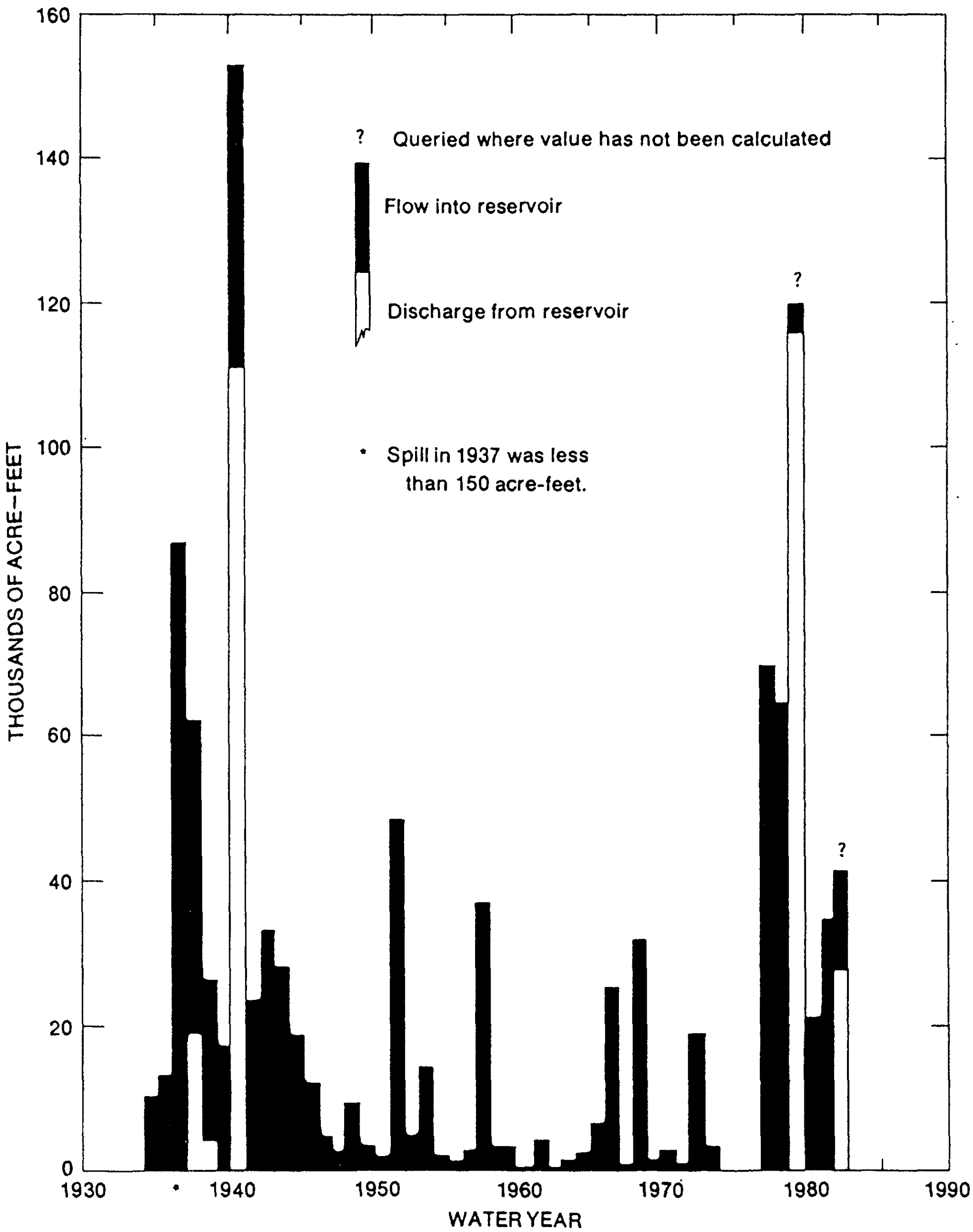


FIGURE 15. - Flow into and discharge from El Capitan Reservoir.

San Vicente Creek upstream from the Santee subarea drains a 74 mi^2 drainage basin; the basin is largely undeveloped and includes an Indian reservation. Flow in the stream is regulated by San Vicente Reservoir (capacity 90,200 acre-ft). San Vicente Reservoir is used to store imported Colorado River water prior to distribution in the San Diego metropolitan area. Since construction of the reservoir, streamflow has occurred only as spill from the reservoir in 1948, 1978, 1980, and 1983 (fig. 16). Leakage from San Vicente Reservoir is much less than from El Capitan Reservoir. Flow into the reservoir represents annual discharge in San Vicente Creek below San Vicente Dam if the reservoir had not been built and is estimated by the city of San Diego Water Utilities Department (G. Lesher, city of San Diego Water Utilities Department, oral commun., 1983). Median annual discharge into San Vicente Reservoir is approximately 2,200 acre-ft (fig. 16).

Forester Creek drains a 24 mi^2, largely urbanized drainage basin. Forester Creek is an ephemeral stream and flow is unmeasured.

Flow in the San Diego River is measured near Santee. Maximum flow was 70,200 ft^3/s on January 27, 1916, and maximum annual discharge was 159,000 acre-ft in 1922. Typically, the San Diego River near Santee flows 278 days per year; in many years the river flows year round. Base flow in the river is maintained by ground-water discharge from the alluvial aquifer, and prior to 1960, by discharge from several small wastewater-treatment plants (L. Michaels, San Diego County Water Authority, written commun., 1984).

Surface-Water Quality

Historical water-quality data for the Santee subarea are summarized in table 8. In the San Diego River below El Capitan Reservoir, dissolved solids ranged from 206 to 635 mg/L; median concentration was 395 mg/L. Sulfate has been an occasional water-quality problem, exceeding the U.S. Environmental Protection Agency (1979) recommended limit for drinking water in 5 percent of the analyses. In San Vicente Creek below San Vicente Reservoir, dissolved solids were higher, ranging from 235 to 941 mg/L; median

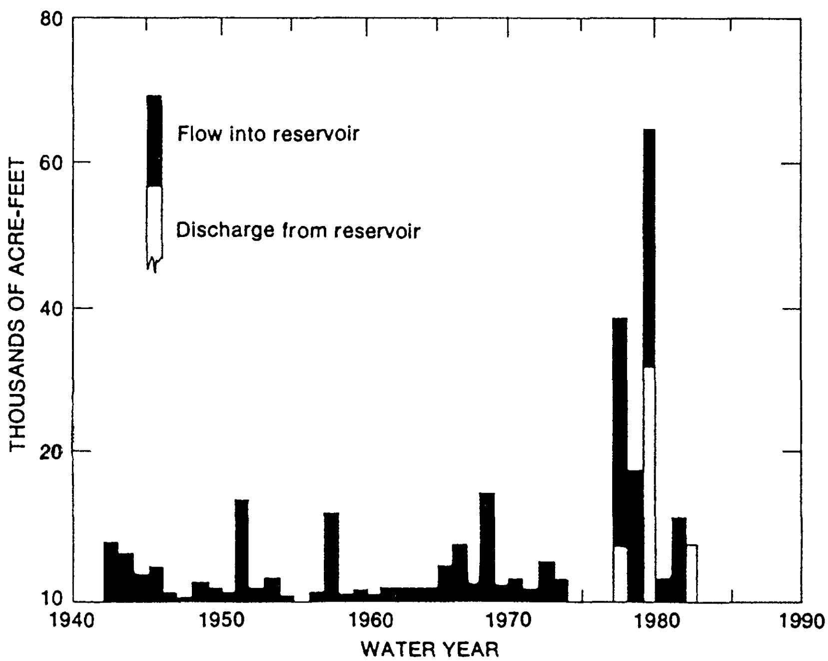


FIGURE 16. - Flow into and discharge from San Vicente Reservoir.

concentration was 684 mg/L. Sulfate exceeded 250 mg/L in 68 percent of the analyses. Differences in dissolved solids, sulfate, and other constituents probably reflect the larger percentage of Colorado River water stored in San Vicente Reservoir.

During the 1983 water year, two samples were collected from the San Diego River below El Capitan Reservoir: one in autumn to reflect base flow, as leakage from El Capitan Reservoir, and another in spring when the reservoir was full and water was being released. Dissolved solids were 308 and 166 mg/L, respectively. Complete analyses are summarized in tables 14-15 (at the end of report). San Vicente Creek was sampled near Lakeside on May 6, 1983; at that time flow was 0.2 ft^3/s and the water had a specific conductance of 1,480 µmho (estimated dissolved solids of 960 mg/L). Water collected in the San Diego River and San Vicente Creek after 1978 had significantly lower median concentrations of dissolved solids, sulfate, and other dissolved constituents than indicated by table 8, using the median test (Neter and Wasserman, 1974) with $\alpha = 0.05$ as the confidence criteria. This is probably the result of a wetter period of record during the last 5 years.

TABLE 8.--Summary of surface-water-quality data for the Santee hydrologic subarea

[Instantaneous discharge, in cubic feet per second; specific conductance, in micromhos per centimeter at 25°C; pH, in units; and constituents, in milligrams per liter unless otherwise noted. --, no data]

Station name	Period of record		Instantaneous discharge	pH	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Alkalinity as $CaCO_3$	Sulfate, dissolved	Chloride, dissolved	Silica, dissolved	Dissolved solids	Nitrate as N	Boron, dissolved, micrograms per liter
San Diego River below El Capitan Reservoir	April 1958 to January 1982	Minimum	--	7.6	24	9.1	24	--	75	25	31	--	206	<0.05	<10
		Median	--	8.1	56	22	56	--	136	126	64	--	395	0.1	150
		Maximum	--	8.9	84	45	107	--	164	268	96	--	635	0.6	900
		Number of samples	0	94	94	94	94	--	84	94	94	--	73	86	15
San Vicente Creek below San Vicente Reservoir	March 1946 to January 1982	Minimum	--	7.1	22	9	38	1.0	77	7.0	49	1.0	235	<0.05	<10
		Median	--	8.2	77	29	104	6.3	116	278	93	11	684	0.07	140
		Maximum	--	9.1	112	45	210	12	184	390	210	45	941	1.1	330
		Number of samples	0	117	117	117	117	93	106	117	117	105	93	98	16
Forester Creek at Mission Gorge Road, near Santee[1]	March 1954 to May 1961	Minimum	0.2	6.8	26	13	48	6.0	59	66	63	5.0	358	<0.05	90
		Median	2	7.3	90	40	240	18	216	270	320	20	1,190	7.1	600
		Maximum	5	8.1	110	65	320	22	376	340	480	25	1,510	29	1,080
		Number of samples	39	38	20	20	32	20	42	20	42	14	20	20	42
San Diego River at Old Mission Dam, near Santee	January 1952 to May 1982	Minimum	0.1	6.6	16	5.2	42	0.2	47	14	54	10	146	<0.05	20
		Median	6	7.6	110	61	290	9.0	254	320	410	25	1,390	1.9	470
		Maximum	2,000	9.0	170	120	490	17	623	600	1,100	50	2,780	10	920
		Number of samples	138	194	73	73	84	75	143	114	187	37	112	73	133

[1]Data from California Department of Water Resources.

Forester Creek drains the urbanized El Cajon drainage basin. Dissolved solids, chloride, sulfate, and occasionally nitrate and boron exceeded drinking water standards and criteria established by the U.S. Environmental Protection Agency (1979). Forester Creek was sampled on May 6, 1983, during the recession of a late spring storm. At that time, water had a specific conductance of 2,700 µmho (estimated dissolved solids of 1,760 mg/L), indicating that water quality probably has not changed since the 1950's and early 1960's.

In the San Diego River at Old Mission Dam, dissolved solids ranged from 146 to 2,780 mg/L. Sulfate and chloride exceeded 250 mg/L in 75 and 95 percent of the analyses, respectively. Water collected in the San Diego River after 1978 had significantly lower median concentrations of dissolved solids, sulfate, chloride, and other dissolved constituents than indicated by table 8. This reflects the same trend observed in the San Diego River below El Capitan Reservoir and San Vicente Creek below San Vicente Reservoir, and is also the result of a wetter period of record. Base flow in the San Diego River at Old Mission Dam had significantly higher concentrations of dissolved solids, sulfate, and chloride, and other dissolved constituents than the median concentrations shown in table 8, using the median test (Neter and Wasserman, 1974) with $\alpha = 0.05$ as the confidence criteria. Maximum concentrations in table 8 reflect base flow water quality, which, in turn, reflects ground-water quality in the western part of the alluvial aquifer.

Ground Water

Peninsular Range Province

Water-bearing characteristics of the crystalline rocks differ with the degree of fracturing and weathering. Ground-water flow is primarily through cracks and fissures in unweathered and slightly weathered granodiorite and tonalite. Wells typically yield less than 5 gal/min and have specific capacities less than 0.1 (gal/min)/ft of drawdown (table 9).

Where tonalite has weathered, wells yield water from pore space in the decomposed-rock matrix. In parts of the Santee subarea, weathering has been extensive and well yields may exceed 100 gal/min, but are typically less than 15 gal/min. Drillers' logs show considerable weathered tonalite buried beneath the alluvial fill. Many deeper wells in alluvium are actually completed in weathered granitic rocks.

Pacific Coastal Plain

The Poway Group yields water to wells, primarily from the coarser conglomerate. Actual yields vary with location and with the depth of the perforated interval (California Department of Water Resources, 1967a). In the Santee subarea, well yields may be as much as 100 gal/min, but typically are less than 20 gal/min.

Alluvial Aquifer

Within the Santee subarea, alluvial deposits occupy a southwesterly trending valley about 13 miles long and 1,500 to 5,000 feet wide. Alluvial thickness exceeds 200 feet near Lakeside and 150 feet east of Moreno Valley. West of Santee, alluvial thickness is less, typically about 70 feet (California Department of Water Resources, 1967a). The aquifer contains about 426,000 acre-ft of fill. Estimates of specific yield range from 0.05 for partly cemented sands and silts to 0.22 for clean sands (Kimble, 1934). If a specific yield of 0.13 is applied, the aquifer has an estimated storage of 55,000 acre-ft. Previous estimates of storage range from 24,000 acre-ft (Kimble, 1934) to 97,000 acre-ft (California Department of Water Resources, 1975). Ground water in the alluvium is unconfined.

TABLE 9.--Water-bearing characteristics of aquifers in the Santee hydrologic subarea

[Data from drillers' information. >, greater than; --, no data]

Geologic unit	Map symbol (see pl. 3)	Exposure in subarea (acres)	Maximum thickness (feet)	Lithologic character	General water-bearing characteristics	Discharge (gal/min)	Specific capacity (gal/min)/ft of drawdown	Trans-missivity (ft^2/d)
Alluvium	Qal	3,440	>200	River and stream deposits of gravel, sand, silt, and clay.	Yields water freely to wells.	As much as 2,000.	As much as 20.	May exceed 5,000.
Older alluvium	QoaL	3,560	>200	River and stream deposits of gravel, sand, silt, and clay. Partly cemented and weathered.	Yields water to wells.	--	--	--
Poway Group	Tp	20,000	1,000	Continental and in part marine conglomerate overlain by sandstone and underlain by sandstone and mudstone.	Yields variable quantities of water to wells.	As much as 100, but typically less than 20.	--	--
Crystalline rocks of the Southern California batholith	Kgp, Kt,Jm	18,800	Basement complex	Primarily unweathered granodiorite and tonalite.	Yields small quantities of water to wells from fractures.	As much as 30, but typically less than 5.	Less than [1]0.1.	--
Deeply weathered exposures of tonalite	Kt	2,200	As much as 100, variable	Deeply weathered tonalite, frequently covered by a thin layer of alluvium.	Yields water to wells from pore space in decomposed-rock matrix and fractures.	As much as 100, but typically less than 15.	As much as 0.7, but typically less than [1]0.4.	--
Santiago Peak Volcanics	KJsp	1,400	Basement complex	Variable, ranges from highly metamorphosed welded tuff to slightly metamorphosed breccia and volcanic conglomerate.	Yields small quantities of water to wells from fractures, may yield larger quantities where metamorphism is slight and weathering intense.	Typically less than [1]2.	--	--

[1]Data from nearby subareas (Izbicki, 1983).

Based on drillers' information and data from Ellis and Lee (1919), well yields may exceed 2,000 gal/min and average more than 500 gal/min. The best producing areas are near Lakeside and east of Moreno Valley. In general, well yields are less in shallower parts of the aquifer west of Santee, but at least one well in this area yields more than 1,000 gal/min.

The most productive materials are clean sands in buried river channels and a layer of coarse gravels near the base of the aquifer east of Moreno Valley. Well logs indicate a greater percentage of silt and clay in the alluvium west of Santee.

Specific capacities are as much as 20 (gal/min)/ft of drawdown. An estimate of aquifer transmissivity can be obtained by multiplying specific-capacity data by 250. This is based on statistical correlations by Thomasson and others (1960) in California's Central Valley, and can be extended to California's coastal and desert basins. Transmissivities may exceed 5,000 ft^2/d. Data are insufficient to delineate areas of high and low transmissivity. However, transmissivities are greater near Lakeside where the aquifer is thicker and east of Moreno Valley where the aquifer contains coarse gravels. Transmissivities are less in the shallow parts of the aquifer west of Santee because the aquifer is thinner and has a higher percentage of silt and clay.

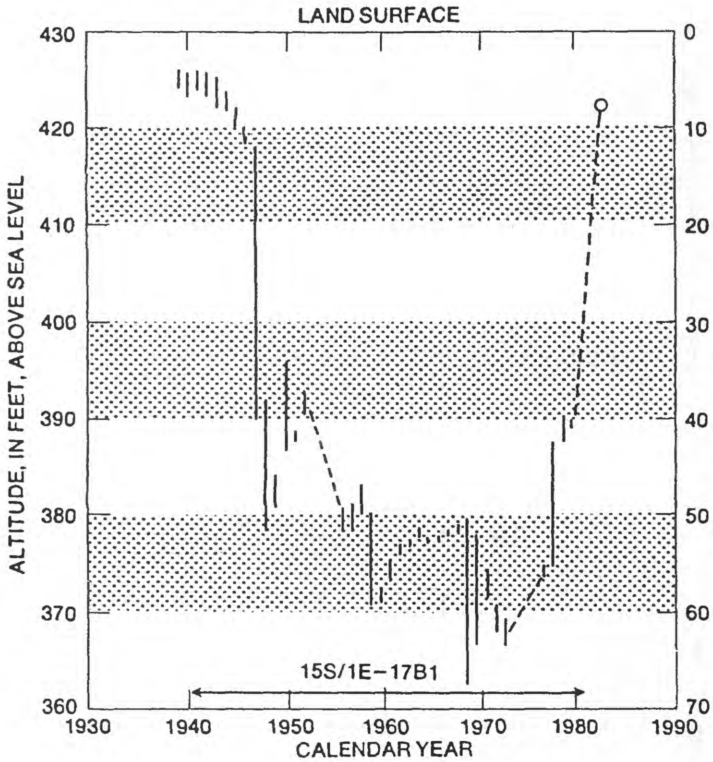
The alluvial aquifer includes older alluvial fill (Pleistocene age) that surrounds younger alluvial fill (Holocene age) in the Santee subarea. Older alluvial fill is composed of gravel, sand, silt, and clay and has been partly cemented and weathered. Well yields, specific yields, specific capacities, and transmissivities are less in older alluvial fill and greater in younger alluvial fill. Hydraulic continuity is assumed between older and younger alluvial fill, and ground water probably moves freely between the two units. Because of greater land-surface elevation of the older alluvial fill, depth to water tends to be greater than in the younger alluvial fill.

Recharge.--Historically, the primary sources of recharge to the alluvial aquifer have been streamflow in the San Diego River and San Vicente Creek. Recharge as streamflow in the San Diego River and San Vicente Creek has been greatly altered since construction of El Capitan and San Vicente Dams. Since the construction of El Capitan Dam in 1935, significant recharge from the San Diego River has occurred in 1937, 1938, 1939, 1941, 1980, and 1983. No significant spills or releases occurred from El Capitan Dam during 1941-80. In years when spills or releases do not occur, recharge from the San Diego River is limited to leakage from El Capitan Dam. Between 1935 and 1974, leakage averaged 140 acre-ft/yr. Since construction of San Vicente Dam in 1943, significant recharge has occurred from San Vicente Creek in 1948, 1978, 1980, and 1983. No spills or releases, and consequently no recharge, occurred from San Vicente Creek during 1948-78. In years when spills or releases do not occur, leakage from San Vicente Dam is an insignificant source of recharge. Because of altered natural recharge patterns, streamflow in Forester Creek, streamflow originating within the subarea, precipitation falling directly on the valley floor, and discharges from municipal wastewater-treatment plants have become more important as sources of recharge.

Occurrence and movement.--Movement of ground water is from the major source of recharge, which is the San Diego River below El Capitan Dam, and from smaller recharge areas in Moreno Valley, downgradient to the discharge area near Mission Gorge. With the exception of evapotranspiration losses, all water entering the alluvial aquifer discharges through the San Diego River at Mission Gorge.

Prior to ground-water development, water levels were within a few feet of land surface much of the year. After 1945, water levels began to decline (fig. 17). By the late 1950's, water levels were as much as 50 feet below land surface in some areas. A water-level-contour map of the alluvial aquifer in spring 1959 (fig. 18) reflects water levels during an extended dry period prior to the beginning of an irrigation season. Depth to water ranged from 14 feet to almost 70 feet below land surface. In general, ground-water drawdown was less in the western part of the aquifer and greater in the eastern part. In spring 1959, 25,800 acre-ft of ground-water storage was available.

Ground-water levels in spring 1983 are shown in figure 19. Ground water rose to present levels after a series of wet years beginning in 1978 (fig. 17). Water levels in wells ranged from 2.6 to 25 feet below land surface, and the San Diego River was a series of interconnected ponds. Water levels in the ponds were maintained throughout the summer by ground-water inflow. Discharge from the aquifer maintained base flow in the San Diego River at Old Mission Dam throughout the summer.



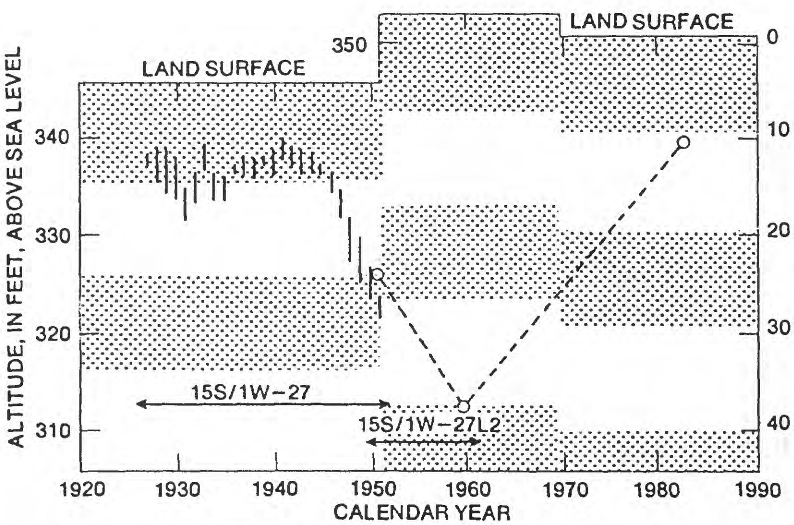
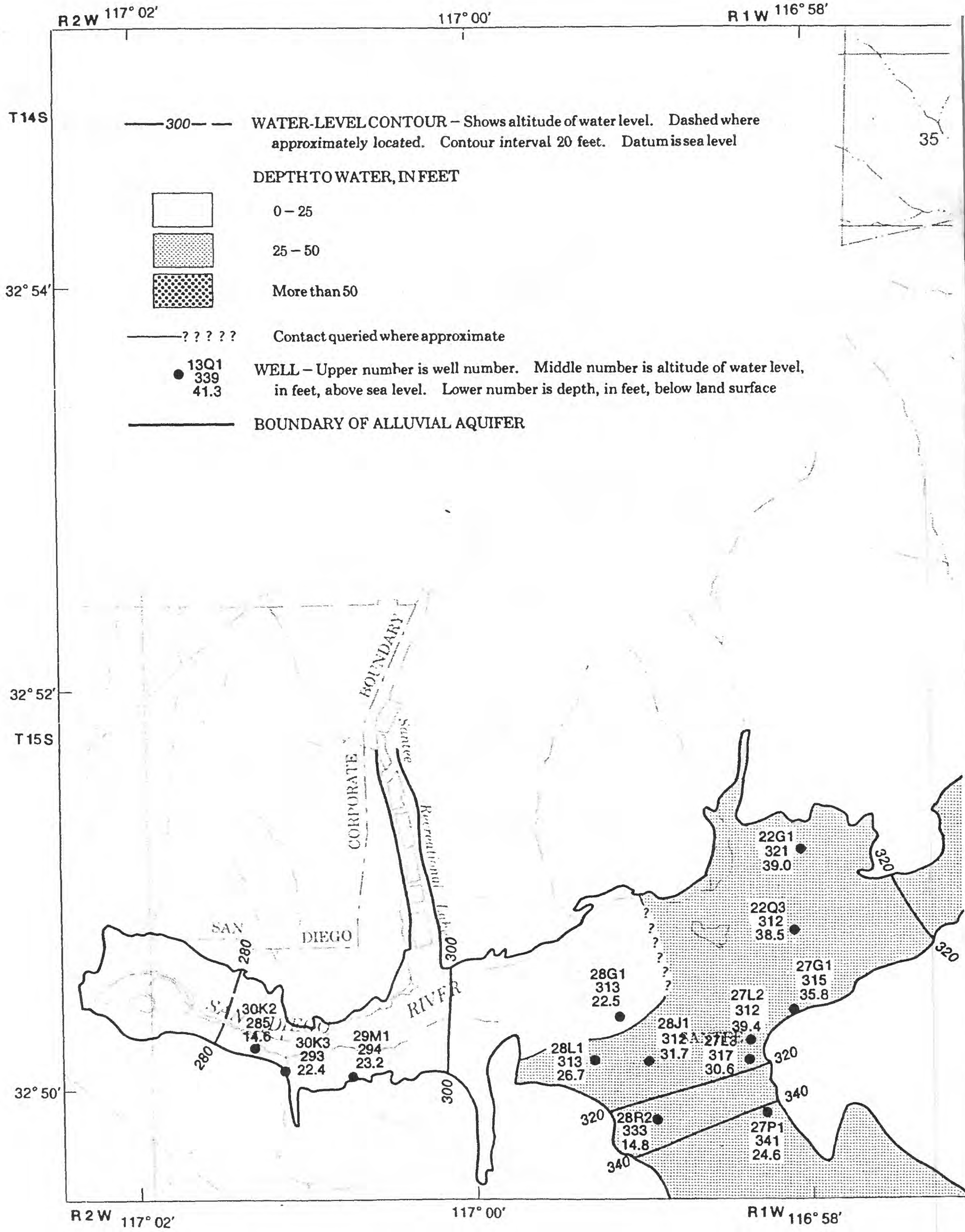


FIGURE 17. - Water levels for wells in the Santee alluvial aquifer. Vertical bar indicates range of water-level fluctuation during year and circle indicates single measurement. (Location of wells shown in figure 33.)



R 2 W 117° 02′
117° 00′
R 1 W 116° 58′
T 14 S
T 15 S
32° 54′
32° 52′
32° 50′
35
300
WATER-LEVEL CONTOUR – Shows altitude of water level. Dashed where approximately located. Contour interval 20 feet. Datum is sea level
DEPTH TO WATER, IN FEET
0 – 25
25 – 50
More than 50
? ? ? ? ?
Contact queried where approximate
13Q1
339
41.3
WELL – Upper number is well number. Middle number is altitude of water level, in feet, above sea level. Lower number is depth, in feet, below land surface
BOUNDARY OF ALLUVIAL AQUIFER
CORPORATE BOUNDARY
SAN DIEGO
Santee Recreational Lakes
SAN DIEGO RIVER
SANTEE
22G1
321
39.0
22Q3
312
38.5
27G1
315
35.8
27L2
312
39.4
27E8
317
30.6
28G1
313
22.5
28J1
312
31.7
28L1
313
26.7
28R2
333
14.8
27P1
341
24.6
30K2
285
14.6
30K3
293
22.4
29M1
294
23.2
280
300
320
340

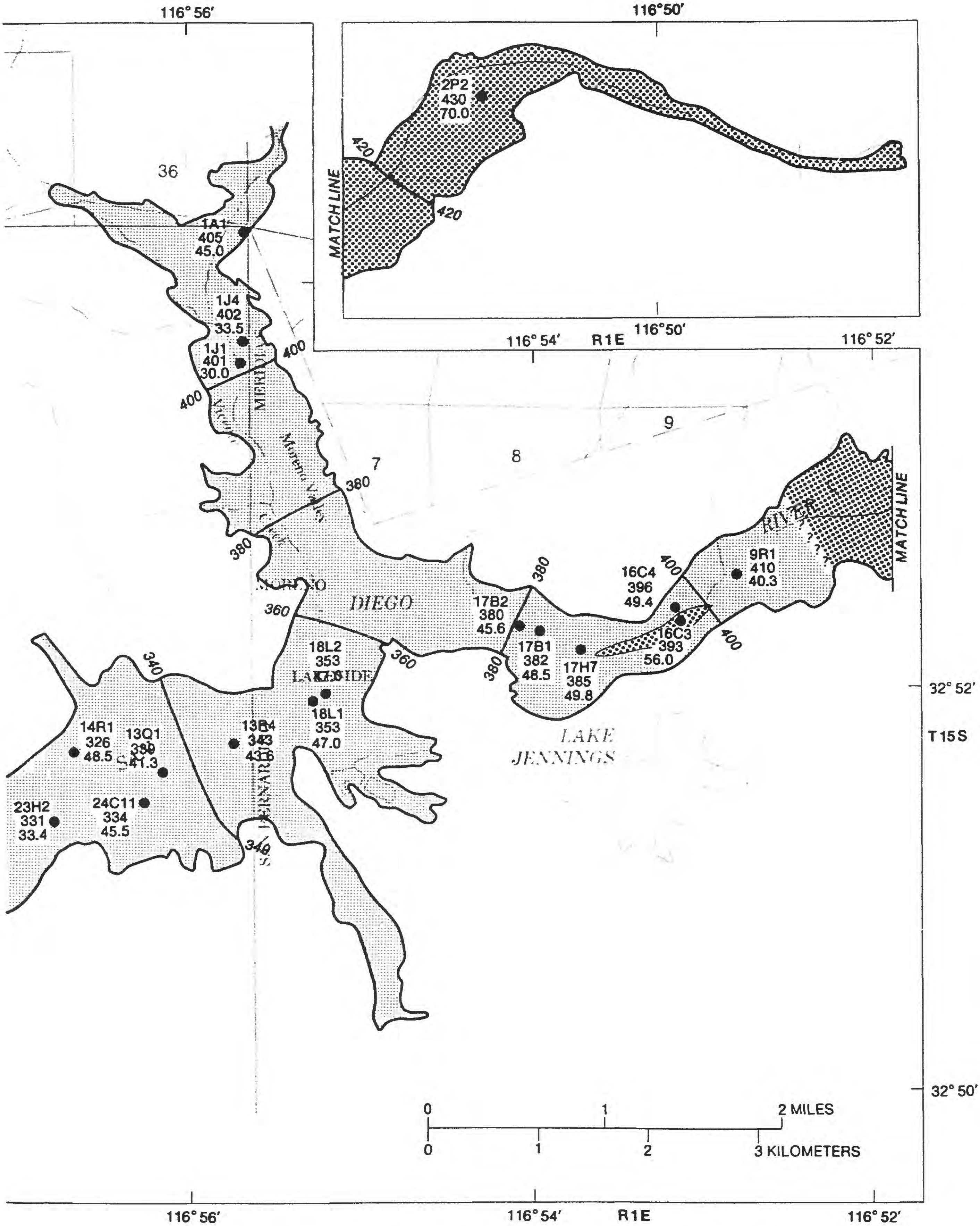
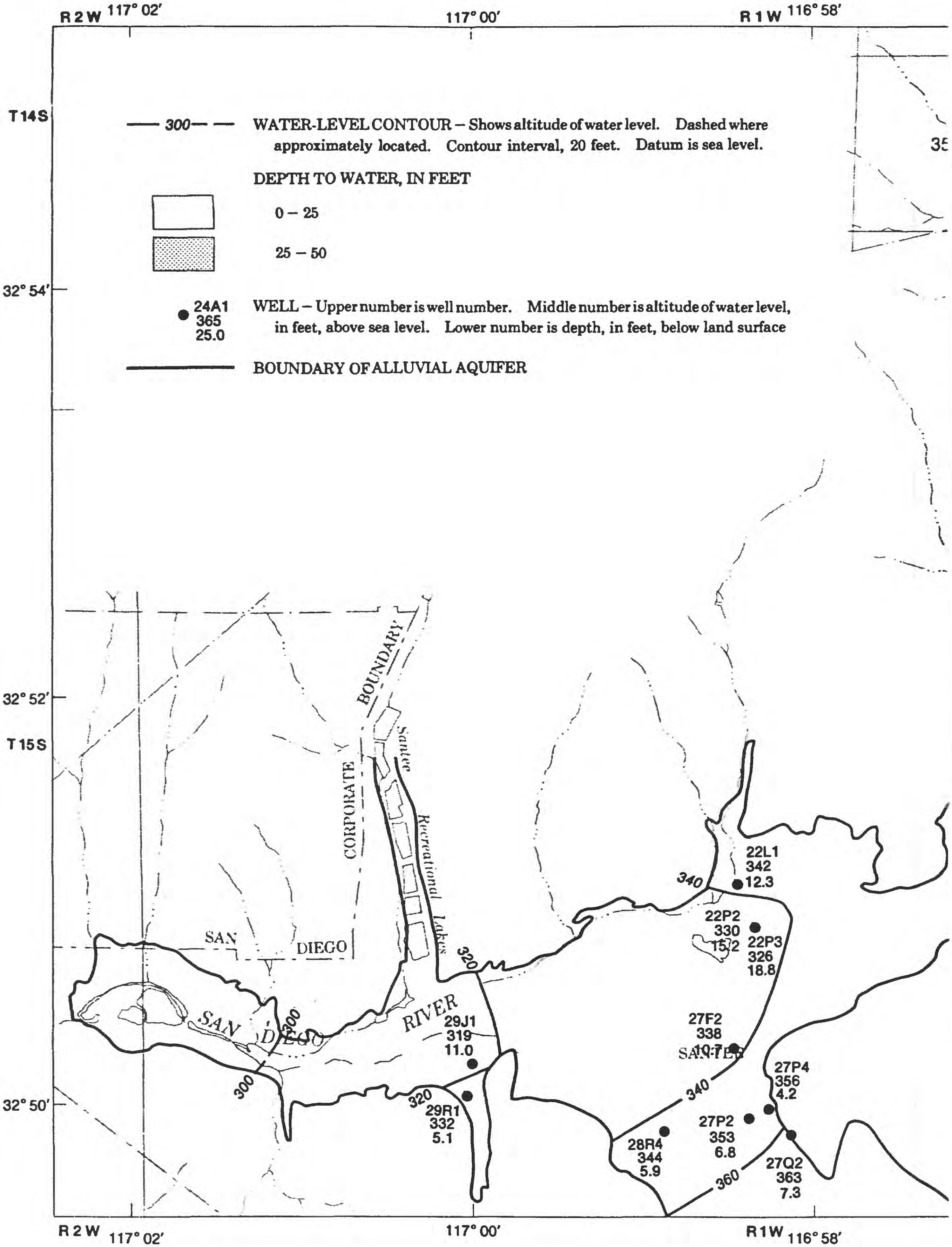


FIGURE 18. - Water-level contours and depth to water in the Santee alluvial aquifer, spring 1959.


R 2 W 117° 02'
117° 00'
R 1 W 116° 58'
T14S
T15S
32° 54'
32° 52'
32° 50'
300 WATER-LEVEL CONTOUR – Shows altitude of water level. Dashed where approximately located. Contour interval, 20 feet. Datum is sea level.
DEPTH TO WATER, IN FEET
0 – 25
25 – 50
24A1 365 25.0 WELL – Upper number is well number. Middle number is altitude of water level, in feet, above sea level. Lower number is depth, in feet, below land surface
BOUNDARY OF ALLUVIAL AQUIFER
CORPORATE BOUNDARY
Santee Recreational Lakes
SAN DIEGO
SAN DIEGO RIVER
SANTEE
22L1 342 12.3
22P2 330 15.2
22P3 326 18.8
27F2 338 10.7
29J1 319 11.0
29R1 332 5.1
27P4 356 4.2
27P2 353 6.8
28R4 344 5.9
27Q2 363 7.3
300
320
340
360
R 2 W 117° 02'
117° 00'
R1W 116° 58'

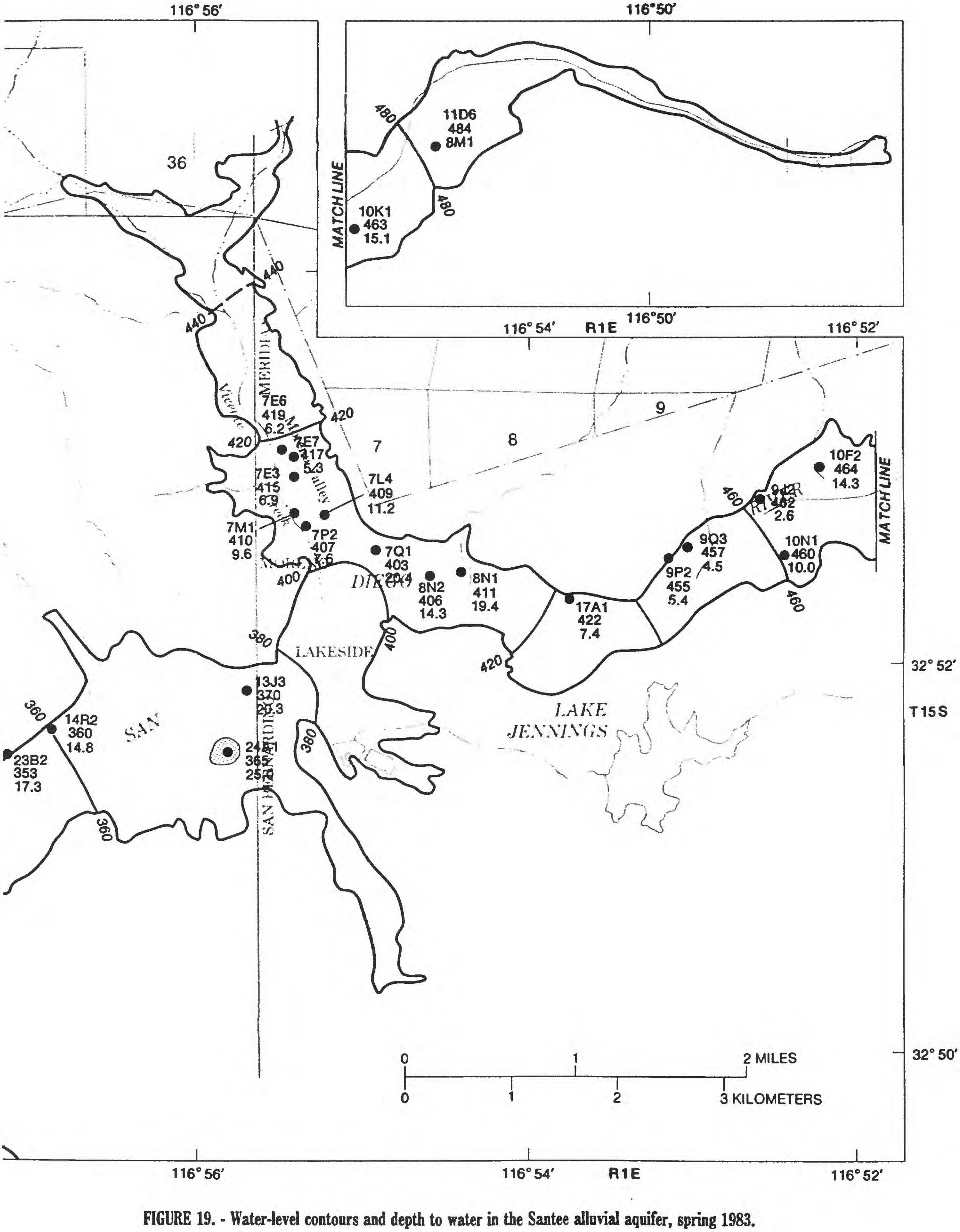


FIGURE 19. - Water-level contours and depth to water in the Santee alluvial aquifer, spring 1983.

Ground-Water Quality

Peninsular Range Province

Water from wells drilled in fractured crystalline rocks in San Diego County, prior to 1967, had a median dissolved-solids concentration less than 500 mg/L (California Department of Water Resources, 1967a). Because wells in this material yield water from fractures, which have little ability to adsorb or filter pollutants, water quality is easily degraded. In the Santee subarea, dissolved-solids concentrations of ground-water samples from wells in crystalline rocks ranged from 230 to 1,920 mg/L; median concentration was 620 mg/L (table 10). Several wells yielded water with nitrate as nitrogen in excess of 10 mg/L, and one well yielded water with a nitrate as nitrogen concentration of 58 mg/L. Some wells have also yielded water with chloride and sulfate in excess of 250 mg/L.

Prior to 1967, water from wells in weathered tonalite in San Diego County had a median dissolved-solids concentration of 500 to 600 mg/L (California Department of Water Resources, 1967a). In the Santee subarea, dissolved-solids concentrations of ground-water samples from wells in weathered tonalite ranged from 410 to 2,810 mg/L; median concentration was 640 mg/L (table 10). Chlorides and sulfates exceeded 250 mg/L in one-half of the measured wells, and nitrate as nitrogen exceeded 10 mg/L in some wells. Current water-quality data are not available for wells yielding water from weathered tonalite.

Pacific Coastal Plain

Ground-water samples from wells in the Poway Group in San Diego County had dissolved-solids concentrations ranging from 450 to 2,000 mg/L, and averaging 800 mg/L (California Department of Water

TABLE 10.--Water quality of aquifers in the Santee hydrologic subarea

[--, no data. Abbreviation: mg/L, milligrams per liter]

Geologic unit	Map symbol (see pl. 3)	Exposure in subarea (acres)	Typical dissolved solids	Typical water type	Water-quality problems
Alluvium	Qal	7,000	Between 260 and 2,870 mg/L; greater than 1,000 mg/L to the west, less than 1,000 mg/L to the east and in Moreno Valley.	Mixed type to mixed cation chloride type in discharge zone.	West of Moreno Valley, dissolved solids, chloride, sulfate, and nitrate; east of and including Moreno Valley, dissolved solids, possibly sulfate and nitrate associated with land use.
Poway Group	Tp	20,000	Between 450 and 2,000 mg/L; average [1]800 mg/L.	Sodium mixed anion[1].	Dissolved solids; possibly chloride and sulfate.
Crystalline rocks	Kgr, Kt, Jm	18,800	Between 230 and 1,920 mg/L; median 620 mg/L.	Mixed type.	Locally, dissolved solids, chloride, sulfate, and nitrate.
Weathered tonalite	Kt	2,200	Between 410 and 2,810 mg/L; median 640 mg/L.	Mixed type to mixed cation chloride.	Do.
Santiago Peak Volcanics	KJsp	1,400	Greater than [2]2,000 mg/L.	Mixed type[2].	Dissolved solids, chloride, and sulfate.

[1]Data from nearby subareas (California Department of Water Resources, 1967a).
[2]Data from nearby subareas (Izbicki, 1983).

Resources, 1967a). Water is generally sodium mixed anion in chemical character, and chloride and sulfate may exceed 250 mg/L. Water-quality data for wells in the Poway Group in the Santee subarea are not available.

Alluvial Aquifer

Historical water quality.--The earliest available ground-water-quality data for the alluvial aquifer were collected in June 1914 by Ellis and Lee (1919). At that time, ground water varied from sodium carbonate to sodium chloride in chemical character. Excluding shallow wells, dissolved-solids concentrations of ground-water samples ranged from 350 to 810 mg/L; median concentration was 600 mg/L. Dissolved-solids concentrations were greater in the western parts of the aquifer and less in Moreno Valley and the eastern parts of the aquifer. Two shallow wells, less than 20 feet deep, yielded water with dissolved-solids concentrations exceeding 1,200 mg/L.

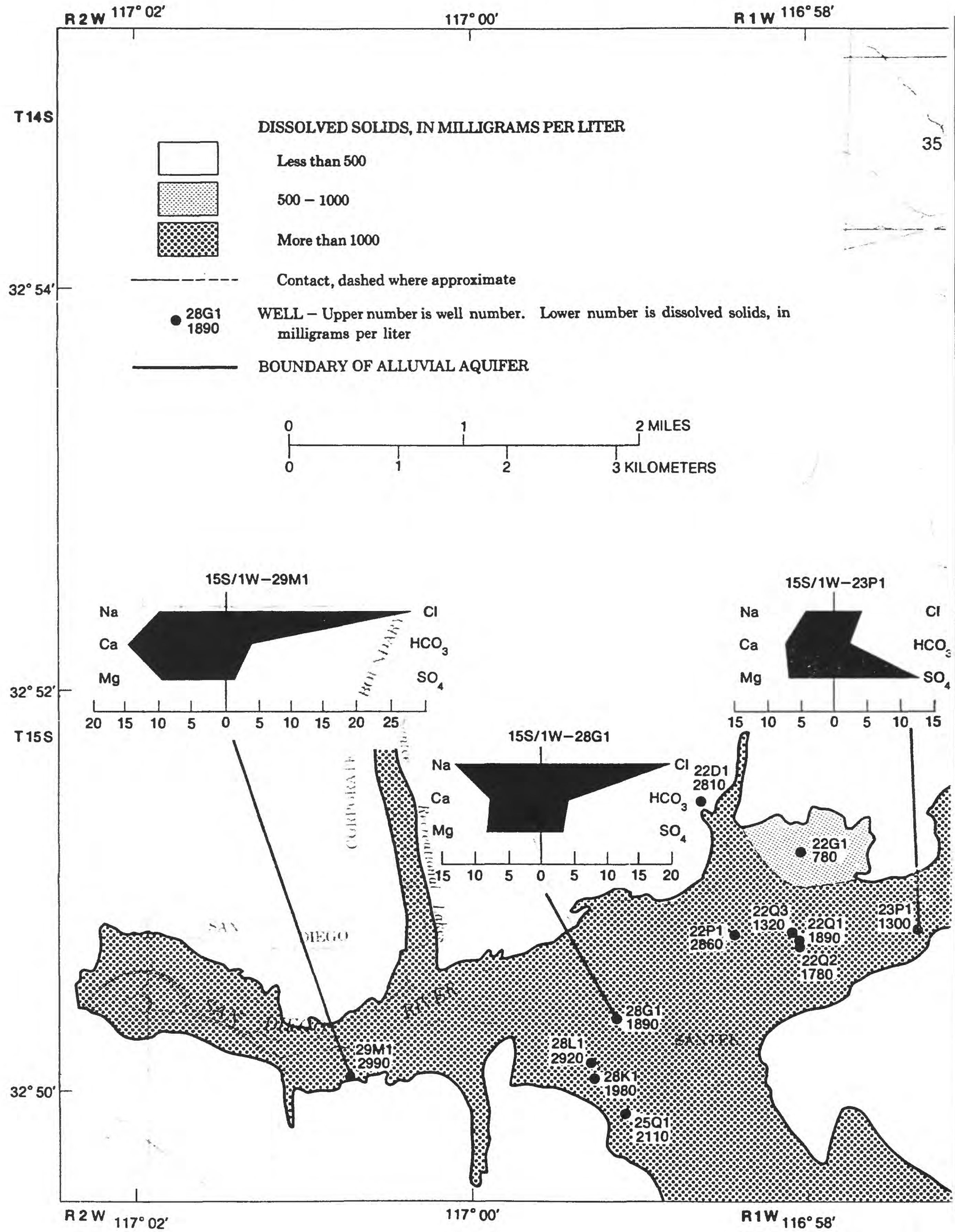
Ground-water-quality data collected in spring 1959 indicate that all but one well west of Moreno Valley yielded water with dissolved solids in excess of 1,000 mg/L, and several wells yielded water with dissolved solids greater than 2,000 mg/L (fig. 20). Water in the eastern part of the alluvial aquifer in spring 1959 was a mixed quality type, with the various cations and anions represented in similar amounts. Sodium, calcium, magnesium, and especially chloride increased downgradient; ground water leaving the aquifer was a mixed cation chloride type.

A plume of high sulfate ground water was located west of the community of Lakeside. Sulfate concentrations from five wells within the plume ranged from 250 to 1,730 mg/L. Stiff diagrams of samples from wells 15S/1W-23H5 and 15S/1W-23P1 reflect typical ground-water quality within the plume. High-sulfate ground water may have been related to industrial use of sulfuric acid in the preparation of decorative sands and gravels. Cation-exchange reactions with calcium- and magnesium-saturated clays may be responsible for increases in calcium and magnesium

$$H_2SO_4 + (Ca/Mg)^{2+}\text{—clay} \rightarrow (Ca/Mg)^{2+} + SO_4^{2-} + (2H^+)\text{—clay}.$$

Historically, nitrates as nitrogen have exceeded 10 mg/L in water from some wells in the alluvial aquifer. Figure 21 shows wells that have yielded water with concentrations of nitrate as nitrogen exceeding the U.S. Environmental Protection Agency (1976) drinking water limit of 10 mg/L. In these wells, located primarily in the western part of the aquifer, concentrations of nitrate as nitrogen as high as 21 mg/L (well 15S/1W-28G1) have been recorded.

Present water quality.--During autumn 1982 and spring 1983, water in the alluvial aquifer was mixed anion bicarbonate in the eastern part of the subarea and mixed anion chloride in the western part. Dissolved-solids concentrations in most wells in Moreno Valley exceeded 1,000 mg/L; concentrations were as high as 2,990 mg/L. Wells 15S/1W-18M1, 15S/1W-22P3, and 15S/1W-22Q5 yielded water with dissolved solids less than 1,000 mg/L, but these wells are near the San Diego River and are affected by infiltration of river water low in dissolved solids. East of Moreno Valley, most wells yielded water with a dissolved-solids concentration less than 500 mg/L, and one well yielded water with an estimated dissolved-solids concentration of 260 mg/L. Some wells downgradient from specific land uses yielded water with estimated dissolved solids in excess of 1,000 mg/L (fig. 22). Dissolved-solids concentrations exceeded the basin objective of 1,500 mg/L in 14 of 52 wells sampled.


R 2 W 117° 02'
117° 00'
R 1 W 116° 58'
T 14 S
T 15 S
32° 54'
32° 52'
32° 50'
35
DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER
Less than 500
500 – 1000
More than 1000
Contact, dashed where approximate
28G1
1890
WELL – Upper number is well number. Lower number is dissolved solids, in milligrams per liter
BOUNDARY OF ALLUVIAL AQUIFER
0 1 2 MILES
0 1 2 3 KILOMETERS
15S/1W–29M1
Na Ca Mg Cl HCO3 SO4
20 15 10 5 0 5 10 15 20 25
15S/1W–23P1
15 10 5 0 5 10 15
15S/1W–28G1
15 10 5 0 5 10 15 20
CORPORATE BOUNDARY
SAN DIEGO
RIVER
SANTEE
22D1
2810
22G1
780
22Q3
1320
22Q1
1890
22Q2
1780
23P1
1300
22P1
2860
28G1
1890
28L1
2920
28K1
1980
25Q1
2110
29M1
2990
R 2 W 117° 02'
117° 00'
R 1 W 116° 58'

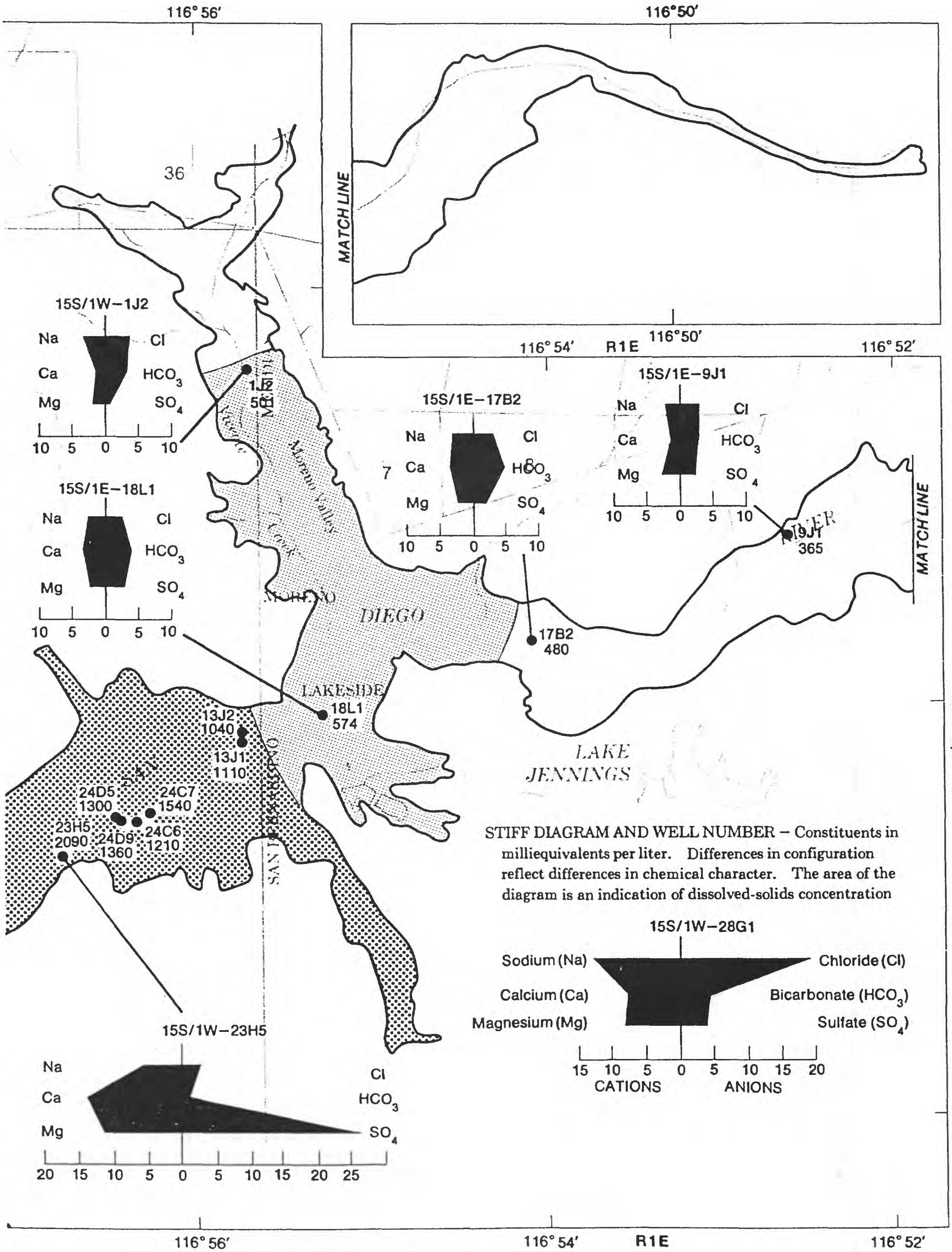
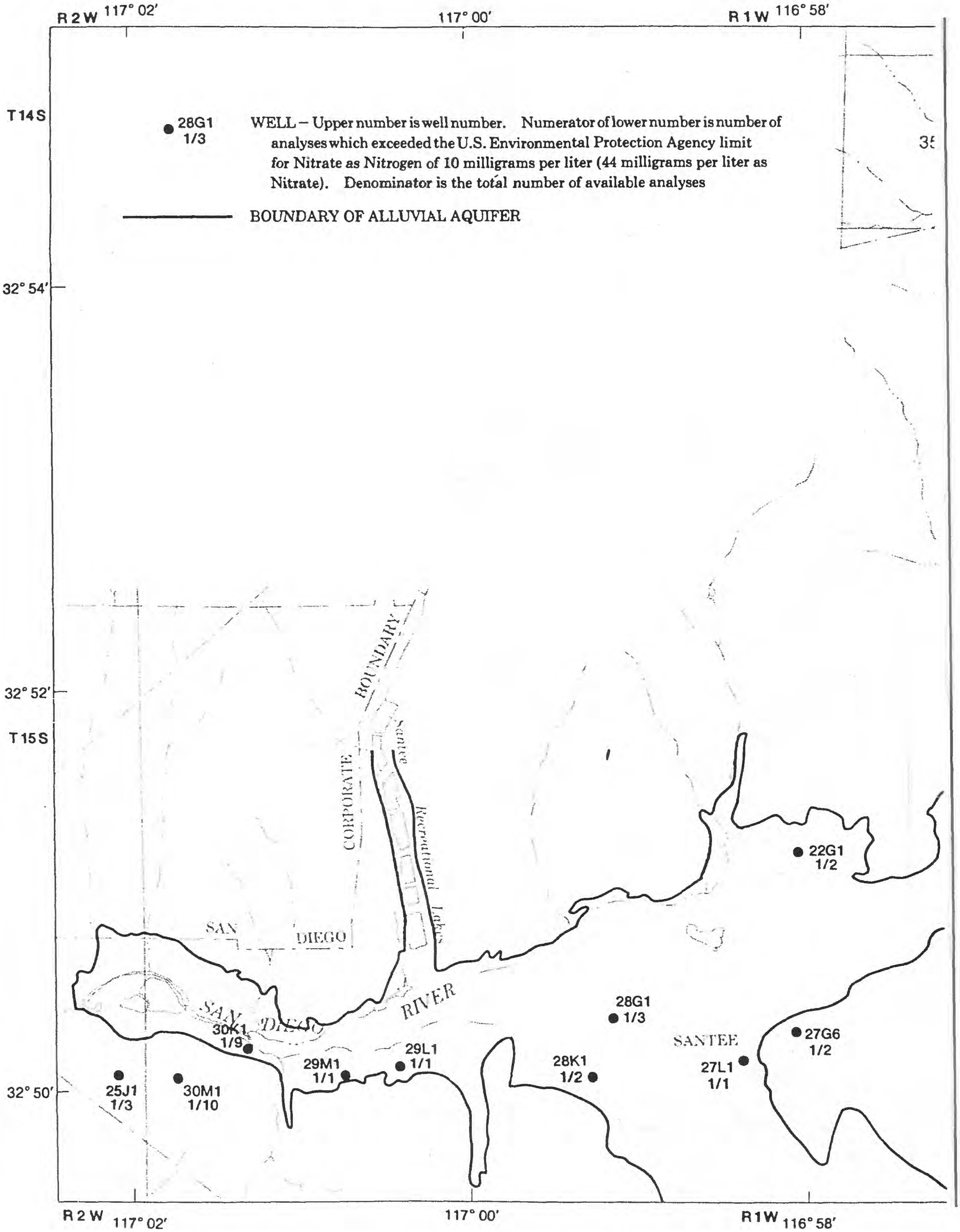


FIGURE 20. - Water quality in the Santee alluvial aquifer, spring 1959.


R 2 W 117° 02′
117° 00′
R 1 W 116° 58′
T 14 S
28G1
1/3
WELL – Upper number is well number. Numerator of lower number is number of analyses which exceeded the U.S. Environmental Protection Agency limit for Nitrate as Nitrogen of 10 milligrams per liter (44 milligrams per liter as Nitrate). Denominator is the total number of available analyses
BOUNDARY OF ALLUVIAL AQUIFER
32° 54′
32° 52′
T 15 S
CORPORATE BOUNDARY
Santee Recreational Lakes
SAN DIEGO
SAN DIEGO RIVER
SANTEE
22G1
1/2
28G1
1/3
27G6
1/2
30K1
1/9
29L1
1/1
29M1
1/1
28K1
1/2
27L1
1/1
25J1
1/3
30M1
1/10
32° 50′
R 2 W 117° 02′
117° 00′
R 1 W 116° 58′

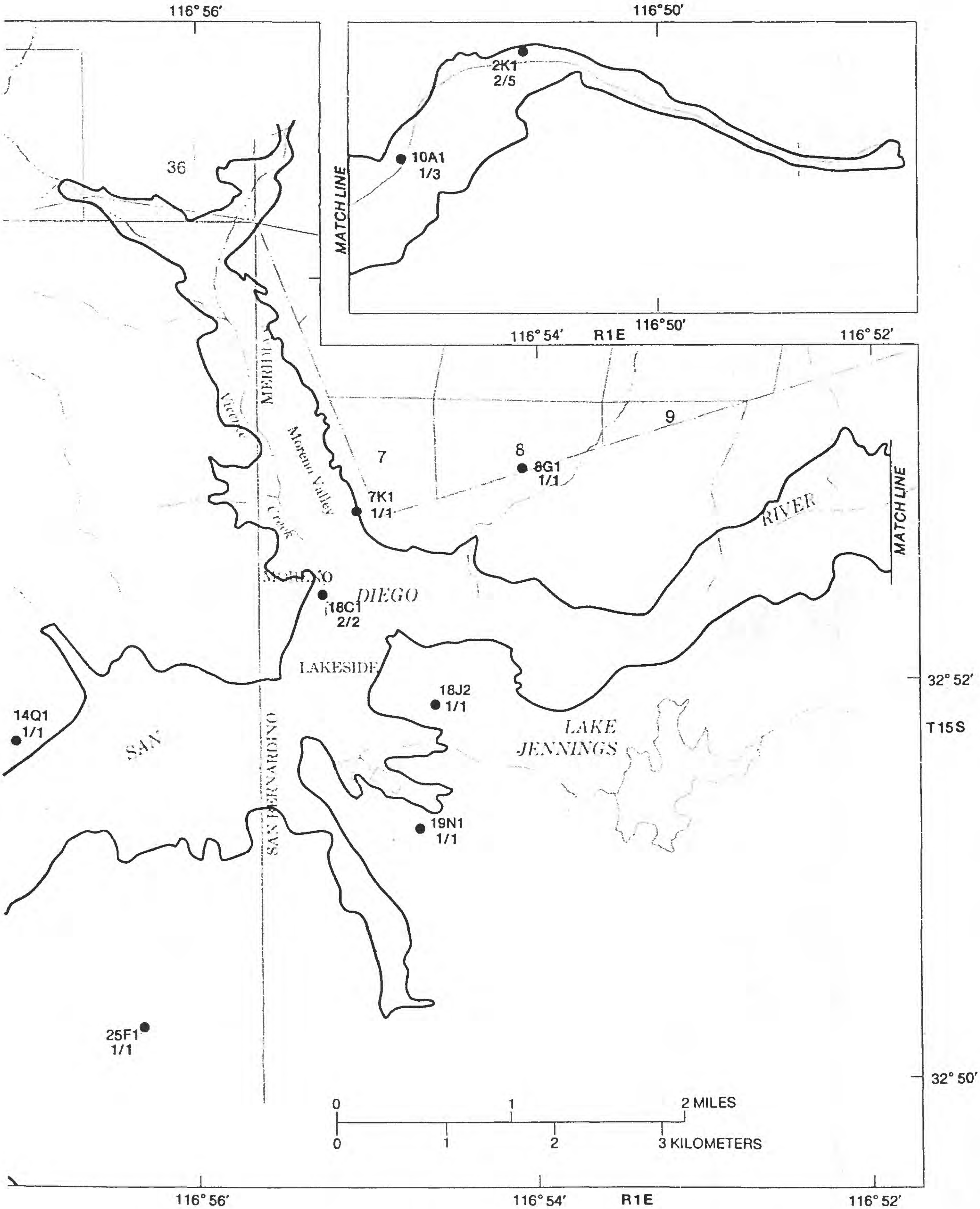
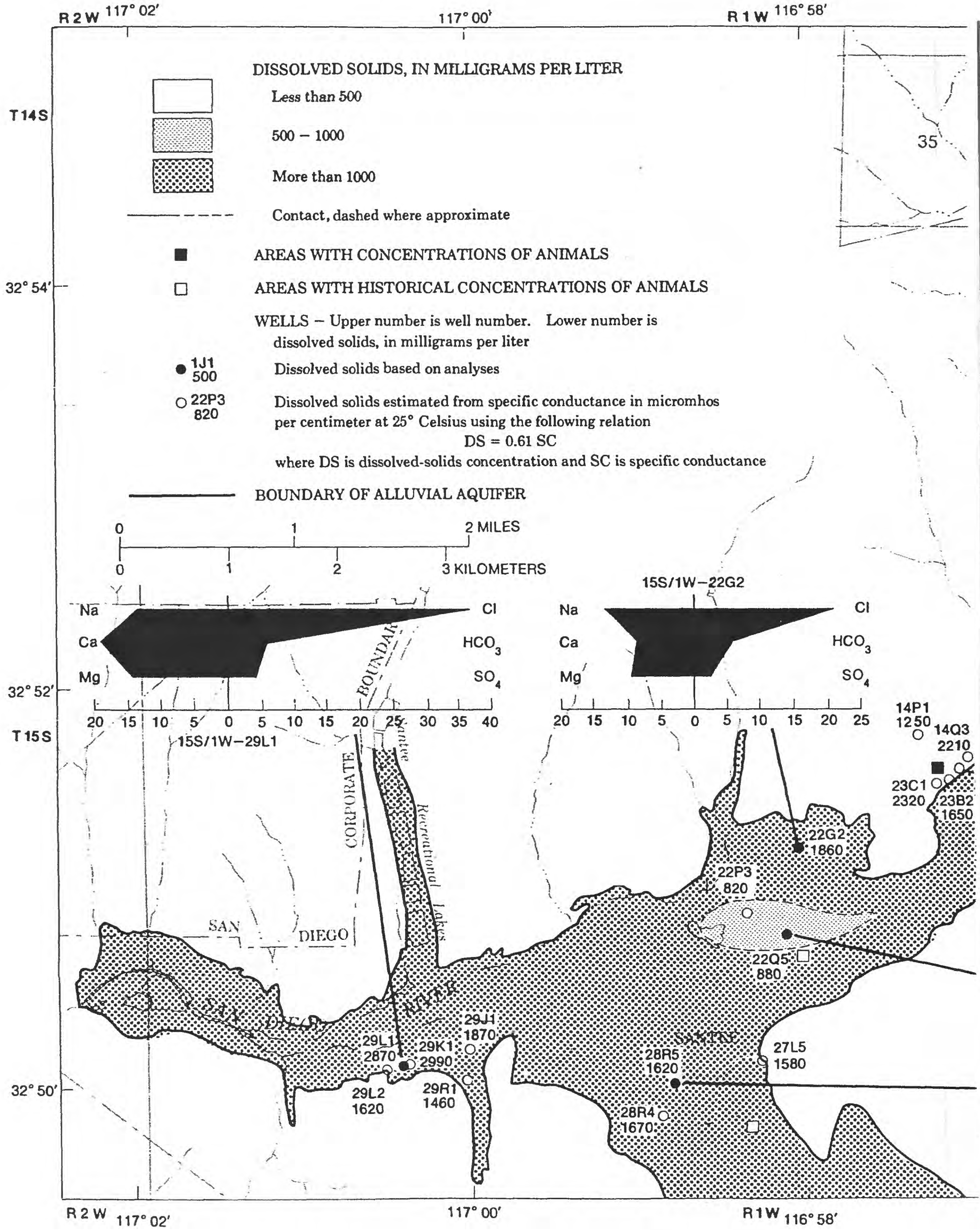


FIGURE 21. - Location of wells which have yielded high concentrations of nitrate, Santee hydrologic subarea, 1959-83.



R 2 W 117° 02′
117° 00′
R 1 W 116° 58′
T 14 S
T 15 S
32° 54′
32° 52′
32° 50′
DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER
Less than 500
500 – 1000
More than 1000
Contact, dashed where approximate
AREAS WITH CONCENTRATIONS OF ANIMALS
AREAS WITH HISTORICAL CONCENTRATIONS OF ANIMALS
WELLS – Upper number is well number. Lower number is dissolved solids, in milligrams per liter
1J1 500
Dissolved solids based on analyses
22P3 820
Dissolved solids estimated from specific conductance in micromhos per centimeter at 25° Celsius using the following relation
DS = 0.61 SC
where DS is dissolved-solids concentration and SC is specific conductance
BOUNDARY OF ALLUVIAL AQUIFER
0 1 2 MILES
0 1 2 3 KILOMETERS
Na Ca Mg Cl HCO3 SO4
20 15 10 5 0 5 10 15 20 25 30 35 40
15S/1W–29L1
15S/1W–22G2
20 15 10 5 0 5 10 15 20 25
35
CORPORATE BOUNDARY
Santee Recreational Lakes
SAN DIEGO
SAN DIEGO RIVER
SANTEE
14P1 1250
14Q3 2210
23C1 2320
23B2 1650
22G2 1860
22P3 820
22Q5 880
29J1 1870
29L1 2870
29K1 2990
29L2 1620
29R1 1460
28R5 1620
27L5 1580
28R4 1670
R 2 W 117° 02′
117° 00′
R 1 W 116° 58′

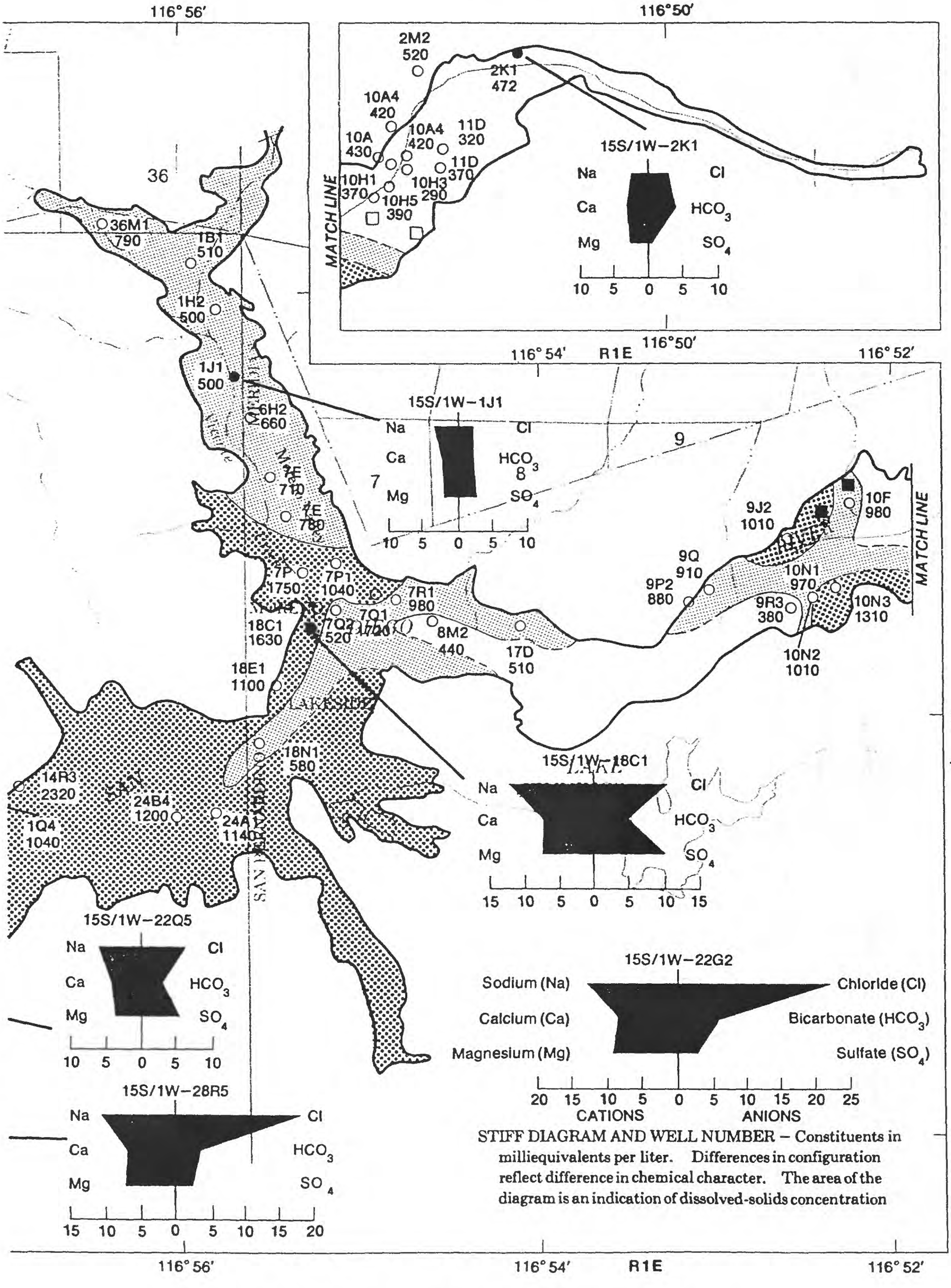


FIGURE 22. - Water quality in the Santee alluvial aquifer, spring 1983.

Field measurements of specific conductance were converted to dissolved-solids concentration using the following relation:

$$DS = 0.61\ SC$$

where

DS is dissolved-solids concentration, in milligrams per liter; and

SC is specific conductance, in micromhos per centimeter at 25°C.

Using the F test (Neter and Wasserman, 1974) with a confidence criteria of $\alpha = 0.05$, the y-intercept was not significantly different from 0 and was omitted from the final equation. The relation was developed, with data collected by the U.S. Geological Survey during autumn 1982 and spring 1983, using linear regression. Eleven samples with dissolved-solids concentrations ranging from 472 to 2,890 mg/L were used, and an R^2 of 0.99 was obtained. This relation is basin specific and care should be used when extrapolating to other areas.

Three of seven wells sampled yielded water with nitrate concentrations in excess of the U.S. Environmental Protection Agency recommended limit for drinking water of 10 mg/L of nitrate as nitrogen (44 mg/L of nitrate as nitrate). One well, 15S/1W-29L1, yielded water with 40 mg/L of nitrate as nitrogen. Chloride exceeded U.S. Environmental Protection Agency recommended limits of 250 mg/L in four of seven wells sampled, and sulfate exceeded limits of 250 mg/L in two of seven wells. High chloride and sulfate concentrations are primarily west of Moreno Valley.

Reclaimed-Water Use

At present, reclaimed water is used for recreational purposes at Santee Lakes, but no additional reclaimed-water-use plans have been developed for the Santee subarea. Although actual effects will depend greatly on the reclaimed-water-management plan ultimately adopted, it is possible to make general statements concerning the effect of reclaimed-water use on water quality and quantity. To be properly evaluated, effects should be compared to and contrasted with possible future trends in water quality and quantity.

Ground water in much of the alluvial aquifer has dissolved-solids concentrations exceeding 1,000 mg/L. Changing land use and decreased natural recharge by construction of San Vicente and El Capitan Dams have contributed to present conditions. As a result of current wet conditions, recharge water with dissolved solids less than 500 mg/L has been spilled or released from upstream reservoirs. However, because ground-water levels are near land surface, much potential recharge water is lost from the subarea as streamflow, and water quality has not improved greatly between 1959 and 1983. If current wet conditions continue, ground-water quality in the alluvial aquifer is likely to improve only slightly in the near future. If conditions become dryer, as in past years, water levels in the alluvial aquifer may decline, but recharge water will not be available and ground-water quality may deteriorate.

Some ground water in the eastern parts of the subarea is used for domestic water supplies. Domestic wells, particularly those which yield water from fractured crystalline rock, may be susceptible to degradation as land use changes and populations of livestock increase.

Reclaimed-Water Quality

Reclaimed water used in this subarea would be treated sewage effluent similar in quality to that produced by the city of San Diego Aquaculture Wastewater Treatment Plant (Larry Michaels, San Diego County Water Authority, oral commun., 1982). The U.S. Geological Survey analyzed treated water collected by plant personnel on May 14, 1983.

Water was sodium-mixed anion in chemical character with a dissolved-solids concentration of 900 mg/L. Concentration of nitrate as nitrogen was 13 mg/L. The quality of reclaimed water was better than that of existing ground water in much of the Santee subarea, and in general, the reclaimed water was acceptable for irrigation of most salt-sensitive plants. Complete analyses are summarized in tables 14-15. A description of treatment plant operations and additional water-quality data are available from the city of San Diego Water Utilities Department (1983).

Effects of Reclaimed Water Use

Reclaimed water used solely as a replacement for irrigation with imported water would probably not much have effect on ground-water quality. At present, small areas are irrigated with imported water. Locally, irrigation return would increase in dissolved solids, chloride, sulfate, and other dissolved constituents. The increase will be proportional to the difference between the quality of present irrigation supplies and the reclaimed water.

If reclaimed water is used as a new source of water supply to develop vacant lands on the valley floor and upland slopes, highly mineralized irrigation-return water could become a major source of recharge to the alluvial aquifer. In areas where ground water is used for domestic water supply, serious water-quality problems could result. In much of the remainder of the subarea, ground-water quality may deteriorate, but because existing water quality is poor this may be of little practical importance. In these areas reclaimed water may represent a new source of water supply. Currently, there is no ground-water storage in the alluvial aquifer for reclaimed water. If reclaimed water were applied under present conditions, water-logging and surface runoff of reclaimed water could result. In some areas, if reclaimed water applied to upland areas is to have adequate soil contact before discharging at land surface, special irrigation techniques and limited application rates may be required. Application rates, volumes, and techniques would have to be evaluated on a site-specific basis.

Reclaimed-water-use plans aimed at improving ground-water quality by pumping water from the subarea and replacing it with reclaimed water lower in dissolved solids may be feasible. Similar plans have been proposed by the San Diego County Water Authority for the San Pasqual subarea (Izbicki, 1983). Dissolved solids less than 500 mg/L in natural recharge water will help meet basin water-quality objectives during wet years. In dry years, management efforts could be facilitated by controlled releases of natural recharge water by El Capitan and San Vicente Dams. Irrigation-return water from hillside agriculture is not an important source of ground-water recharge, and it will not complicate reclaimed-water-use plans. Urbanization and industrialization in the Santee area may have unforeseen effects on ground-water quality.

TIJUANA HYDROLOGIC SUBAREA

Geology

The Tijuana hydrologic subarea lies entirely within the Pacific Coastal Plain. In this area, the Pacific Coastal Plain consists of a series of highly dissected marine terrace deposits underlain by partly consolidated sediments (fig. 23). The entire sequence forms a stairstep series of steep-sided, mesa-like terraces.

Marine terrace deposits are flat-lying, partly cemented cobble conglomerates, generally less than 25 feet thick, overlying the San Diego Formation.

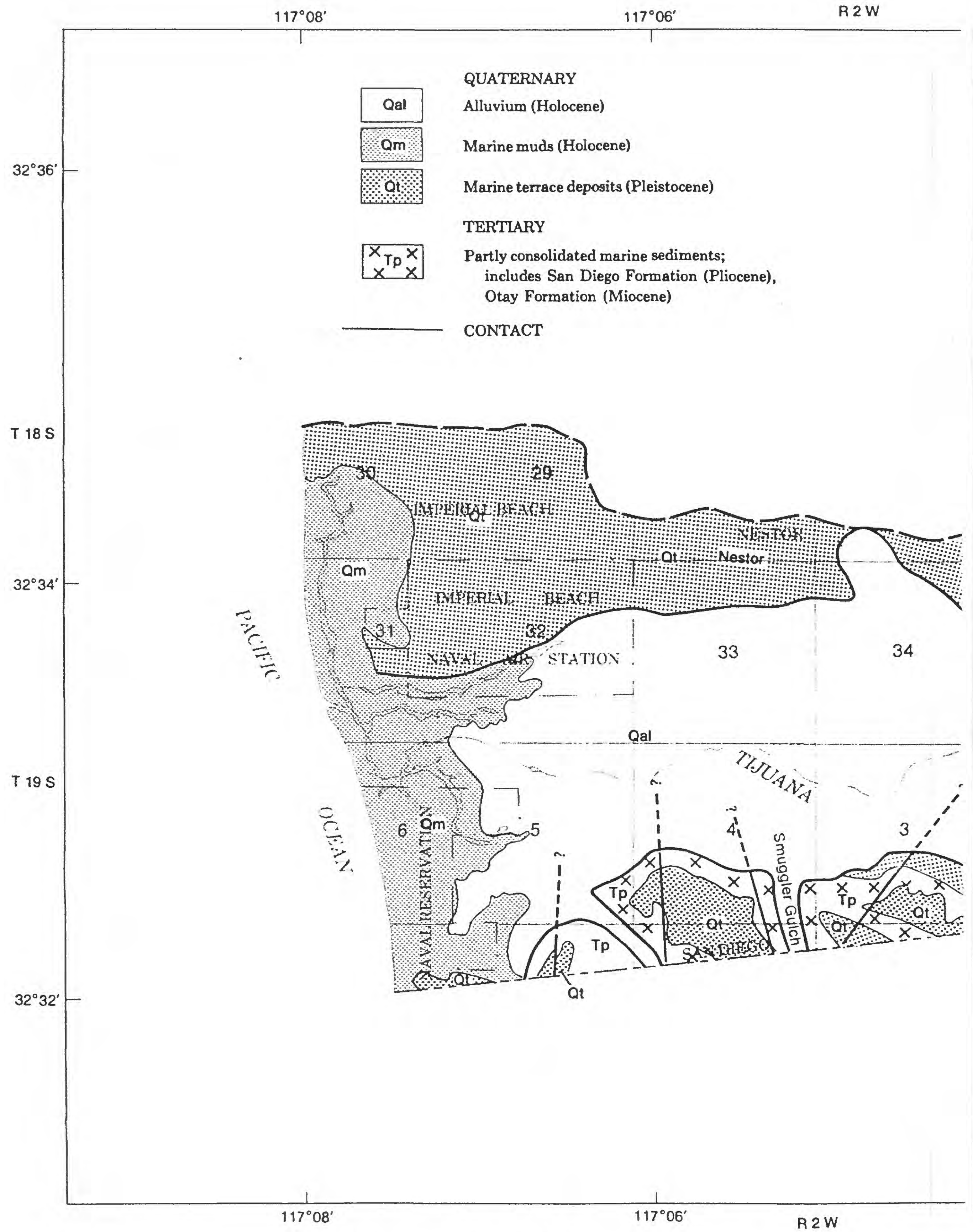
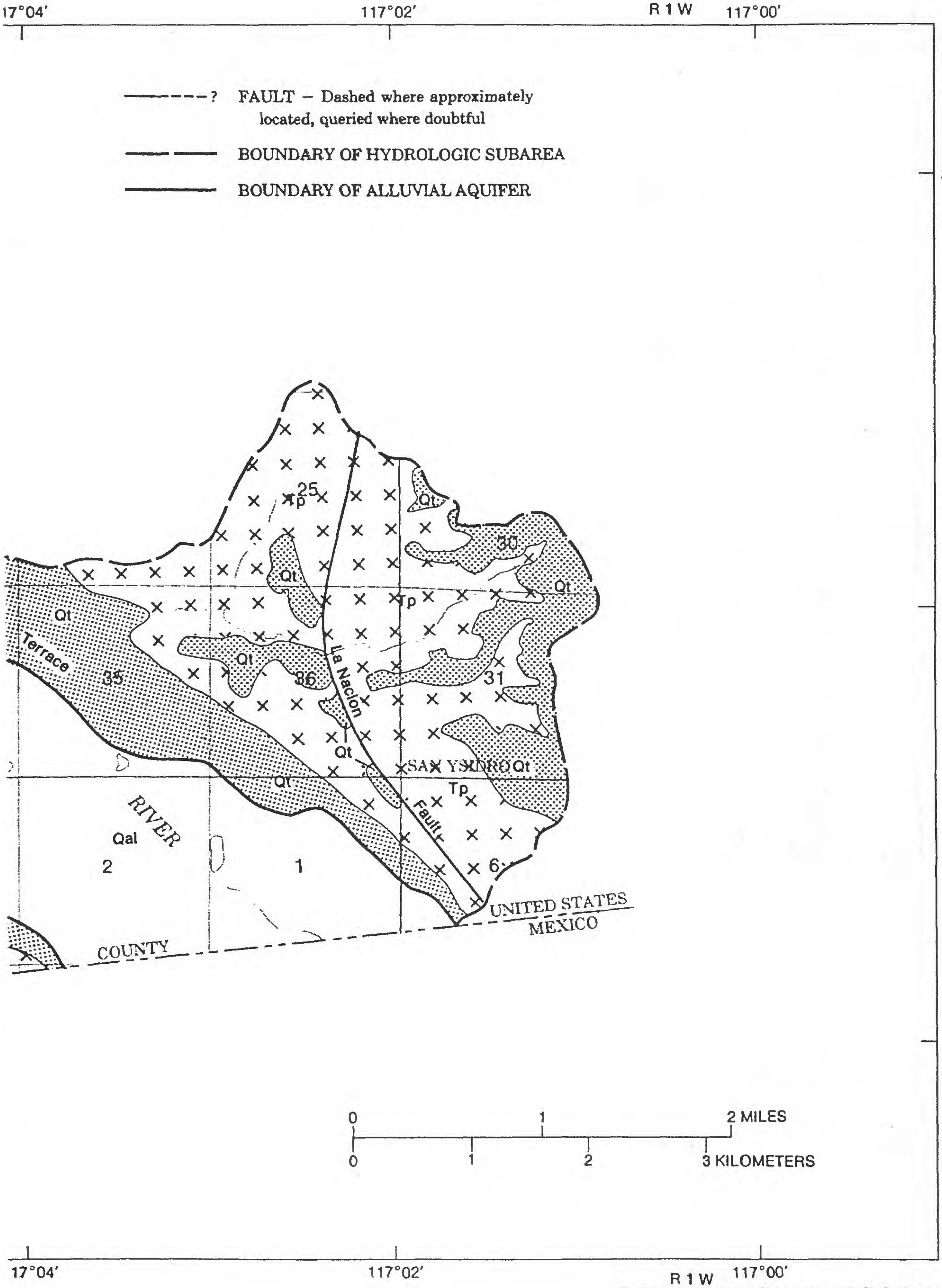


FIGURE 23. - Generalized geology of the Tijuana hydrologic subarea.



Geology modified from Ellis and Lee (1919), California Department of Water Resources (1967a), Artim and Pinckney (1973), and Ziony (1973)

The San Diego Formation consists of partly consolidated marine sandstone, siltstone, and conglomerate interspersed with volcanic tuff and bentonite; maximum thickness is about 1,250 feet (U.S. Geological Survey, 1966). East of the La Nacion fault, tuffaceous sandstone of the Otay Formation (Artim and Pinckney, 1973) is exposed. Rocks of the Poway and La Jolla Groups are found at depth. Stratigraphy in the Tijuana subarea is complex. Identifiable layers frequently pinch out entirely in a few feet; consequently, correlation of well logs is difficult and frequently impossible. Total thickness of sediments in the Tijuana subarea is unknown, but some wells penetrate more than 1,400 feet without reaching the basement complex.

The Pacific Coastal Plain has been incised by the Tijuana River and the valley formed has been partly backfilled with alluvium to a point 16 miles inland in Mexico. The maximum thickness of alluvial fill is about 200 feet near the Pacific Ocean.

The La Nacion fault (Artim and Pinckney, 1973) and several smaller faults cross the Tijuana subarea. The smaller faults may be associated with the Rose Canyon fault, which is 20 miles north of the subarea (Wiegand, 1970). Parts of some of these faults have been active in Quaternary times, although it is unclear if there has been movement in the Holocene Epoch. Faulting has undoubtably contributed to difficulty in correlating deep well logs from the Tijuana subarea.

Soils

Four soil associations have been identified in the Tijuana subarea: Huerhuero-Stockpen; Redding-Olivenhain; a miscellaneous association of broken land and terrace escarpments; and Visalia-Tujunga (fig. 24). The discussion that follows is based primarily on work by the U.S. Soil Conservation Service (1973).

The Huerhuero-Stockpen association has developed over marine terrace deposits of the Tijuana subarea. The association is characterized by gently sloping Huerhuero and Stockpen soils. Both soils are more than 5 feet thick, but contain clay horizons with infiltration rates less than 0.06 in/h.

The Redding-Olivenhain association has developed on exposed slopes of the partly consolidated sediments. In the Tijuana subarea, this association is dominated by steeply sloping Olivenhain soils more than 5 feet thick. Smaller amounts of thinner (3.5 feet) Diablo and Linne soils are also within this association. All these soils contain clay horizons with low (less than 0.06 in/h for Olivenhain soils) to moderate (0.2 to 0.63 in/h for Linne soils) infiltration rates. Redding soils from which the association takes part of its name are not within the Tijuana subarea.

Where marine terrace deposits are partly eroded and the underlying sediments are faulted, soils belong to a miscellaneous association of broken land and terrace escarpments and sloping gullied land. Soils developed from remnants of marine terrace deposits are thin (between 1.5 and 3.5 feet) and characterized by a hardpan at a depth of 3 feet. Poor infiltration and rapid runoff have resulted in erosion of exposed slopes. Small areas of thick soils (more than 5 feet), with moderate slopes and high infiltration rates (6.3 to 20 in/h) throughout the entire soil profile, may be near stream channels and on small hills within this association.

The Visalia-Tujunga association has developed over alluvial deposits in the Tijuana River valley. Soils of the Visalia-Tujunga association are greater than 5 feet thick and typically sandy; infiltration rates exceed 20 in/h for Tujunga soils. The Tijuana subarea contains extensive areas of Chino soils with considerable clay and lower infiltration rates (0.2 to 0.63 in/h). Chino soils tend to be saline. The primary limitations on application of reclaimed water to soils of the Visalia-Tujunga association are: a high water table, often within several feet of land surface much of the year; low infiltration rates of Chino soils; and flood hazards.

Surface Water

Streamflow Characteristics

Surface drainage in the Tijuana hydrologic subarea is through the Tijuana River. The Tijuana River is an intermittent stream which drains approximately 1,700 mi^2; 70 percent of the drainage area, or almost 1,200 mi^2, is in Mexico. Flow in the river is regulated by three reservoirs: Morena (capacity 50,200 acre-ft), Barrett (capacity 44,800 acre-ft), and Rodriquez (capacity 111,000 acre-ft). The maximum flow in the Tijuana River was 33,500 ft^3/s on February 21, 1980, near Nestor (fig. 25). The maximum annual discharge was 586,000 acre-ft in water year 1980. Streamflow data are summarized in table 11.

TABLE 11. - Summary of discharge for the Tijuana River near Nestor (11013500)

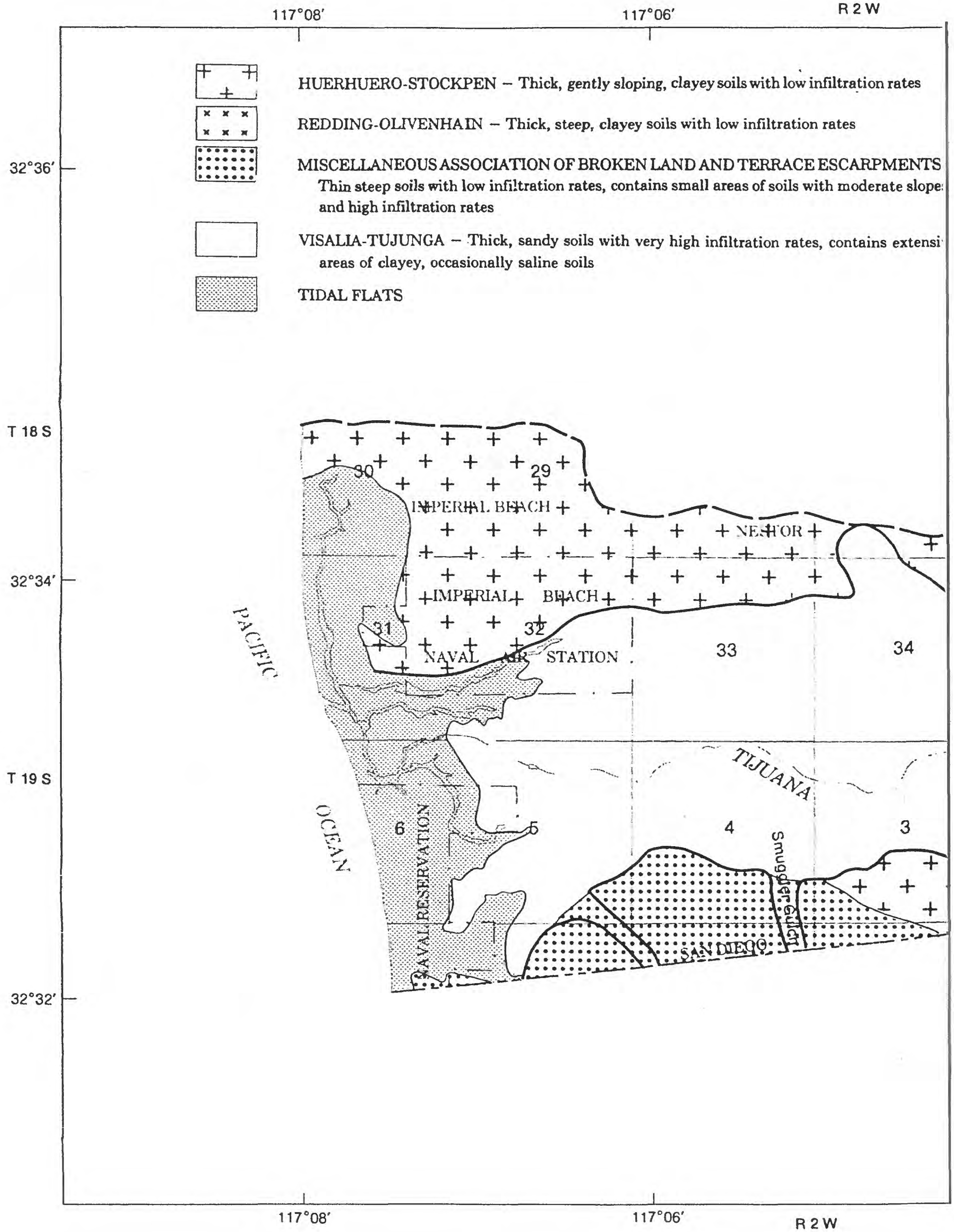
[Flow regulated by Morena Reservoir, capacity 50,200 acre-ft; Barrett Reservoir, capacity 44,800 acre-ft; and Rodriguez Reservoir, capacity 111,000 acre-ft]

Period of record	October 1914 to September 1915; October 1936 to September 1981
Drainage area	1,695 mi^2
Annual discharge	
Average	33,200 acre-ft
Median	659 acre-ft
Median number of days with discharge greater than 0.1 ft^3/s	16
Maximum discharge for period of record	
Instantaneous	33,500 ft^3/s
Annual	586,000 acre-ft

Surface-Water Quality

During the 1983 water year, two samples were collected from the Tijuana River near the international boundary: one in autumn to reflect base flow, and another during the recessional flow of a late spring storm. Dissolved-solids concentrations were 1,850 and 376 mg/L, respectively.

In autumn 1982, water in the Tijuana River exceeded the U.S. Environmental Protection Agency (1979) recommended limit for drinking water for chloride of 250 mg/L. Ammonia and Kjeldahl-nitrogen concentrations were 13 and 47 mg/L as nitrogen, respectively, and nitrate and nitrite were less than the detection limit, indicating strongly reducing conditions. At the time of sampling, October 7, 1982, an oily black substance was observed floating on the water surface. The U.S. International Boundary Commission routinely measures coliform counts of several million organisms per liter during base flow in the Tijuana River (Al Goff, U.S. International Boundary and Water Commission, oral commun., 1983). Water-quality analyses are given in tables 14-15 (at the end of report).


117°08'
117°06'
R 2 W
HUERHUERO-STOCKPEN – Thick, gently sloping, clayey soils with low infiltration rates
REDDING-OLIVENHAIN – Thick, steep, clayey soils with low infiltration rates
MISCELLANEOUS ASSOCIATION OF BROKEN LAND AND TERRACE ESCARPMENTS
Thin steep soils with low infiltration rates, contains small areas of soils with moderate slope and high infiltration rates
VISALIA-TUJUNGA – Thick, sandy soils with very high infiltration rates, contains extensi areas of clayey, occasionally saline soils
TIDAL FLATS
32°36'
T 18 S
32°34'
T 19 S
32°32'
30
29
IMPERIAL BEACH
NESTOR
IMPERIAL BEACH
31
32
NAVAL AIR STATION
33
34
PACIFIC
OCEAN
TIJUANA
6
5
4
3
NAVAL RESERVATION
Smuggler Gulch
SAN DIEGO
117°08'
117°06'
R 2 W

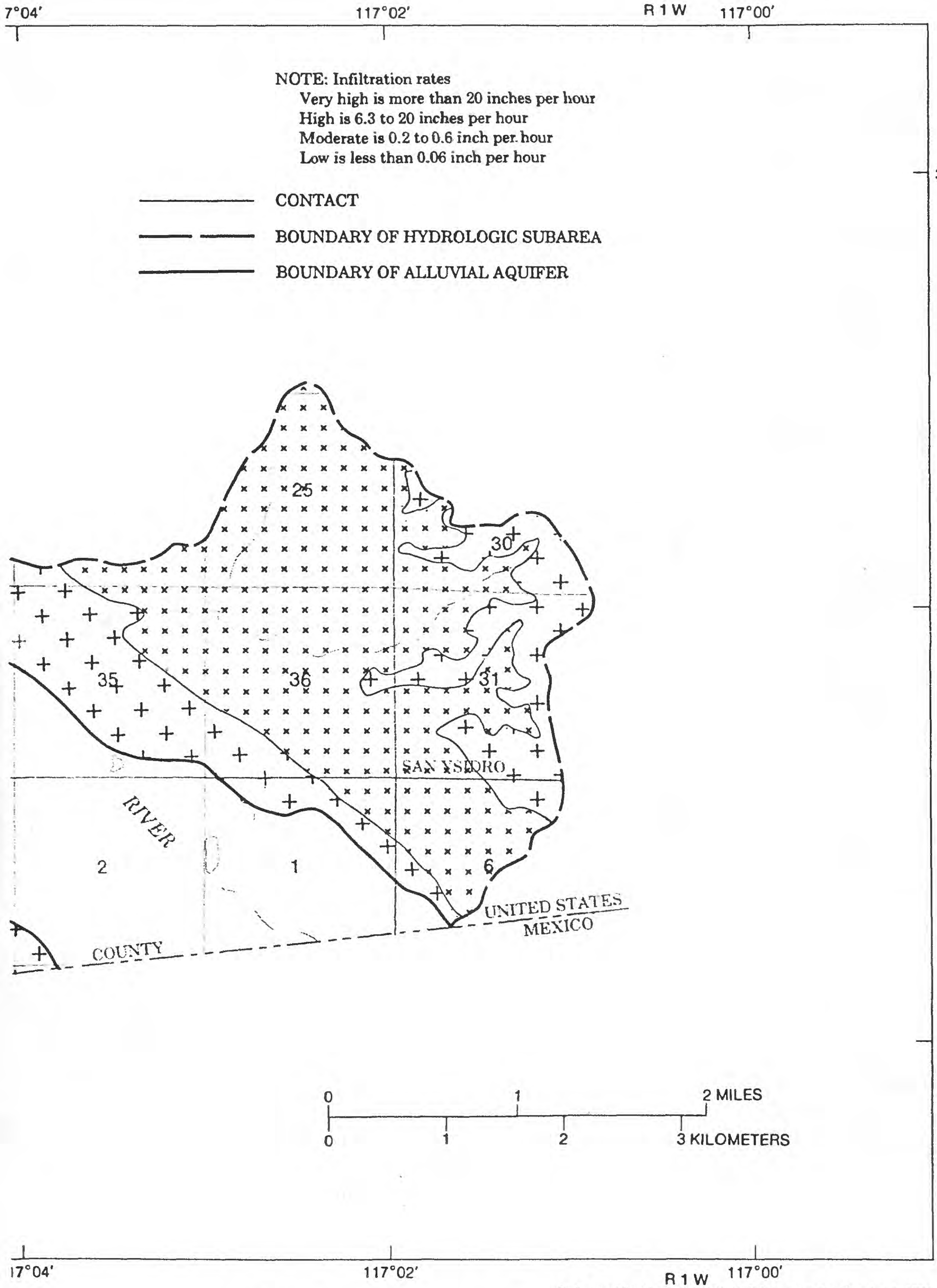


FIGURE 24. - Soil association in the Tijuana hydrologic subarea.

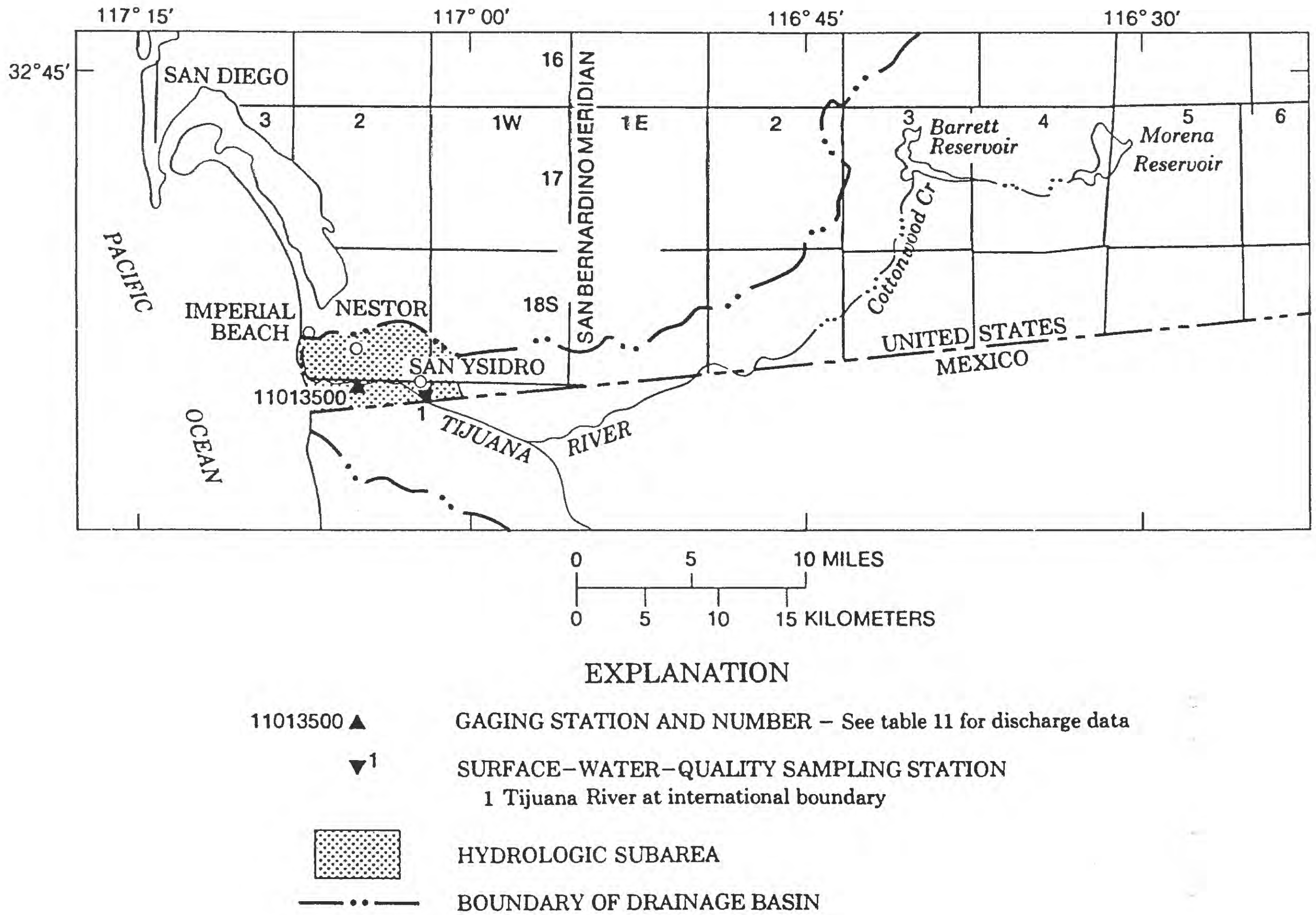


FIGURE 25. - Location of gaging station and surface-water-quality sampling station in the Tijuana hydrologic subarea.

Ground Water

Pacific Coastal Plain

With the exception of the Nestor terrace, marine terrace deposits in the Tijuana subarea are generally above the regional water table and do not yield water to wells. In spring 1983, water levels in the Nestor terrace ranged from 15 and 20 feet below land surface, and the water table probably intersected the marine terrace deposits.

Several wells in the Tijuana subarea yield water from partly consolidated sediments at depths as great as 1,250 feet (U.S. Geological Survey, 1966). Well yields are as much as 1,000 gal/min, but average 350 gal/min. Some deep wells have flowed at the rate of 60 gal/min. Specific capacities of wells in the partly consolidated sediments average 4.4 (gal/min)/ft of drawdown (table 12). Well yield and specific capacity decrease with increasing percentage of volcanic tuff or bentonite at the perforated

TABLE 12.--Water-bearing characteristics of aquifers in the Tijuana hydrologic subarea

[Data from drillers' information. --, no data]

Geologic unit	Map symbol (see fig. 23)	Exposure in subarea (acres)	Maximum thickness (feet)	Lithologic character	General water-bearing characteristics	Discharge (gal/min)	Specific capacity (gal/min)/ft of drawdown	Trans-missivity (ft^2/d)
Alluvium	Qal	5,000	150±	River and stream deposits of gravel, sand, silt, and clay.	Yields water freely to wells.	As much as 2,000; averages 550.	As much as 30; averages 15.	As much as 7,500.
Marine terrace deposits	Qt	3,170	300	Partly cemented cobble conglomerate.	Permeable, but frequently above regional water table.	--	--	--
Partly consolidated marine sedimentary rocks	Tp	2,100	1,250	Marine sandstone, siltstone, and conglomerate with tuff beds.	Yields water to wells.	As much as 1,000; averages 350.	Averages 4.4.	--

interval. Ground-water movement is probably from recharge areas east of the Tijuana subarea toward the Pacific Ocean.

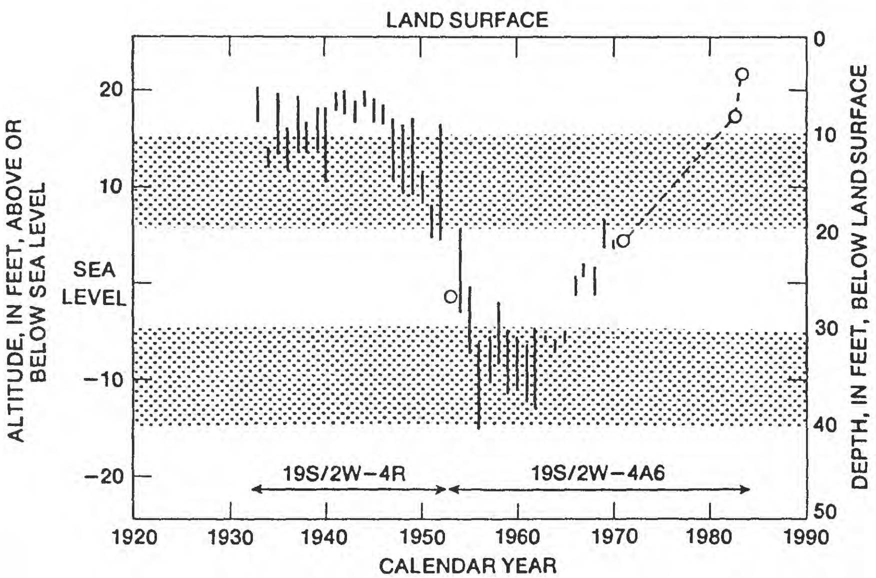
Alluvial Aquifer

Alluvial fill extends from the Pacific Ocean to a point 16 miles inland in Mexico. The westernmost 4.5-mile segment of alluvial fill within the Tijuana hydrologic subarea is in the United States; this segment, exposed and under the tidal flats, is 1 to 1.5 miles wide and occupies 5,000 acres. Previous estimates of storage are between 50,000 and 80,000 acre-ft for the part of the alluvial aquifer in the United States, and 137,000 acre-ft for the entire alluvial aquifer (California Department of Water Resources, 1975).

Based on drillers' information, well yields in the alluvial aquifer may exceed 2,000 gal/min and average 550 gal/min. The principal water-yielding zone is a layer of coarse sand and gravel near the base of the aquifer. Specific capacities are highest for wells which intercept this layer and may exceed 30 (gal/min)/ft of drawdown. For the aquifer as a whole, specific capacity averages 15 (gal/min)/ft of drawdown. Aquifer transmissivities, estimated by multiplying specific capacity by 250, are as high as 7,500 ft^2/d and average 3,800 ft^2/d. This method, from correlations by Thomasson and others (1960) in California's Central Valley, has been routinely extended to California's coastal and desert basins.

Recharge.--Recharge to the alluvial aquifer originates primarily outside the hydrologic subarea as flow in the Tijuana River. In a typical year, all flow in the Tijuana River becomes ground-water recharge. In a wet year considerable potential recharge leaves the subarea as streamflow and is discharged to the Pacific Ocean. Between autumn 1982 and spring 1983, water levels in the aquifer rose as much as 7 feet in response to the wet winter and high streamflows. This represents an increase in ground-water storage of almost 2,700 acre-ft. This figure was calculated from a water-level-change map using an average storage coefficient of 0.20.

Occurrence and movement.--Movement of ground water is from the major source of recharge, the Tijuana River near the international boundary, downgradient to the discharge area near the Pacific Ocean. Prior to ground-water development, water levels were about 10 feet below land surface much of the year. After World War II and the beginning of extensive ground-water development, water levels began to decline (fig. 26). During this time, water was exported from the subarea by the California Water and Telephone Company. By the early 1950's, water levels were below sea level in parts of the aquifer. Maximum water-level drawdown throughout the aquifer occurred in the early 1960's. In spring 1961, during an extended dry period, depth to water ranged from 5.3 to 43.6 feet below land surface, and water levels were as much as 10.9 feet below sea level (fig. 27). In spring 1961, 15,600 acre-ft of ground-water storage was available.



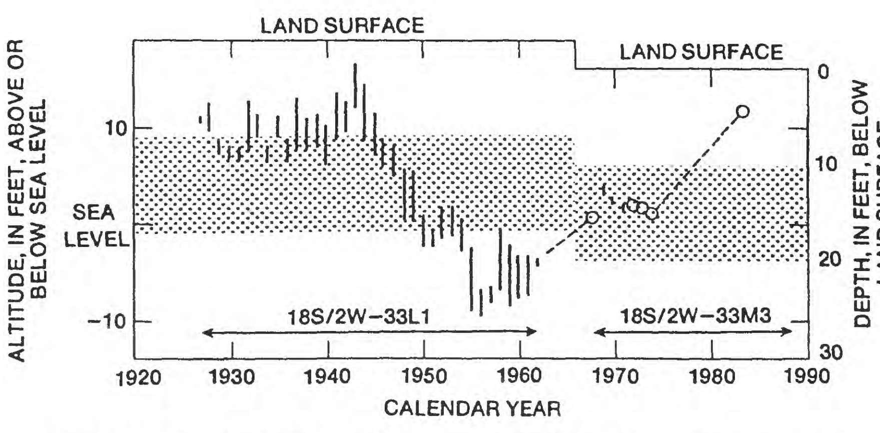


FIGURE 26. - Water levels for wells in the Tijuana alluvial aquifer. Vertical bar indicates range of water-level fluctuation during year and circle indicates single measurement. (Location of wells shown in figure 34.)

In spring 1983, water levels in wells ranged from above land surface to almost 15 feet below land surface (fig. 28). The Tijuana River was a series of interconnected ponds. Water levels in the ponds were maintained throughout the summer by ground-water inflow.

Ground-Water Quality

Quality of ground water in the Tijuana subarea is generally poor; however, some deeper wells yield water of good quality from partly consolidated sediments. Typical dissolved-solids concentrations, water type, and water-quality problems are summarized by geohydrologic unit in table 13.

Pacific Coastal Plain

Water from partly consolidated sediments underlying the Tijuana subarea is generally a sodium-chloride water type, and the ratio of sulfate to bicarbonate, in milliequivalents per liter, is generally less than 1. Historical analyses of dissolved solids from 15 wells ranged from 710 to 2,360 mg/L; median concentration was 1,230 mg/L. No relation was apparent between dissolved solids and well depth.

Figure 29 is a plot of dissolved solids as a function of time from well 18S/2W-33L10. In general, ground-water chemistry has not changed greatly with time. Increasing dissolved solids and sulfate in some wells may be caused by corrosion of the well casing and subsequent leakage of ground water from the alluvial aquifer rather than by changes in ground-water chemistry at the perforated interval.

Other water-quality problems in partly consolidated sediments are chloride and occasionally sulfate in excess of the U.S. Environmental Protection Agency (1979) recommended limits of 250 mg/L for drinking water. Some wells yield water with a sodium absorption ratio greater than 10. Such water may have an adverse effect on soil structure and crop yields unless soil amendments are used. Sodium adsorption ratio (SAR) is defined as:

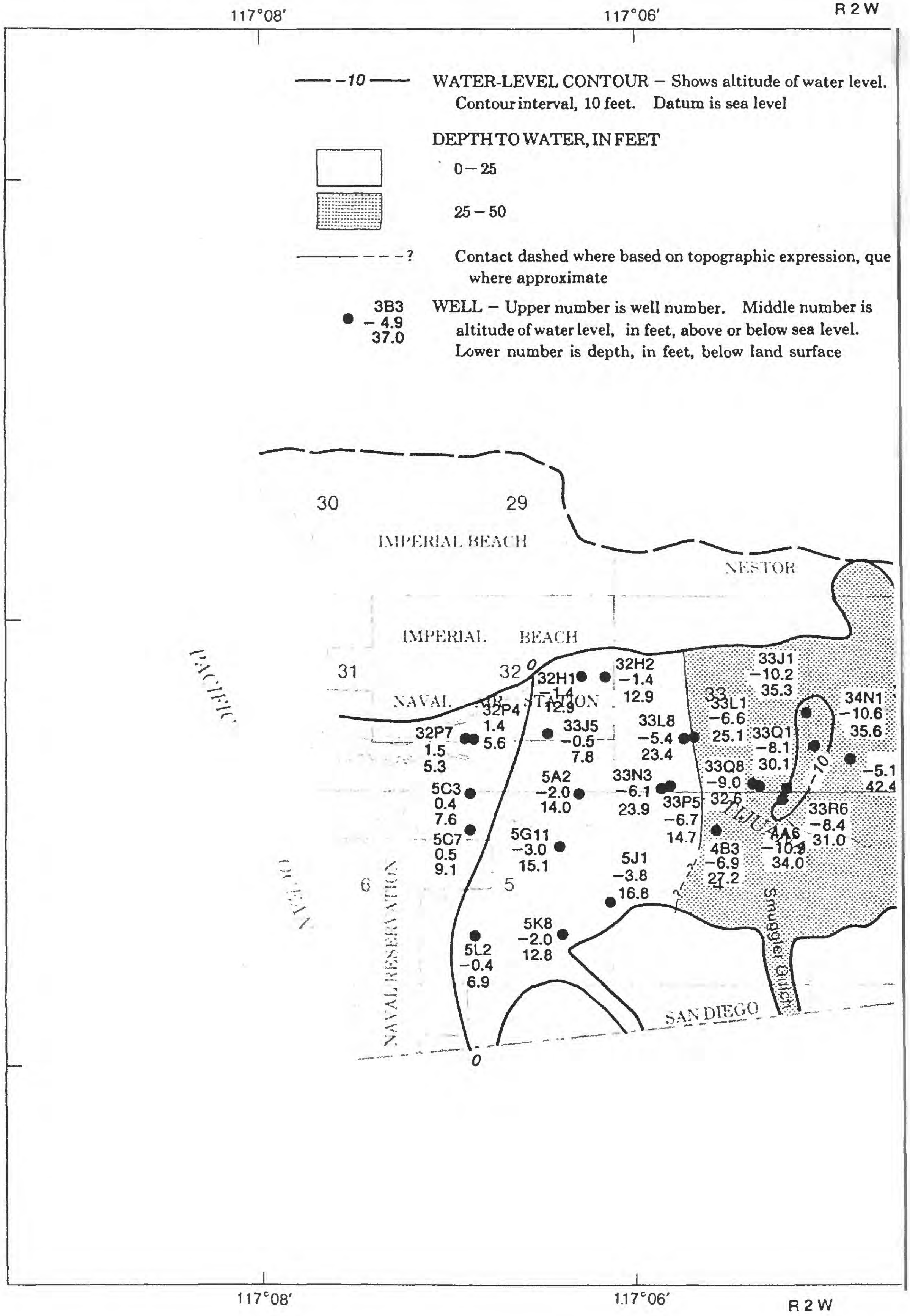
$$SAR = \frac{(Na^{+})}{\sqrt{\dfrac{(Ca^{2+}) + (Mg^{2+})}{2}}}$$

where ion concentrations are in milliequivalents per liter (U.S. Salinity Laboratory, 1954).

TABLE 13.--Water quality of aquifers in the Tijuana hydrologic subarea

[--, no data. Abbreviations: mg/L, milligrams per liter, meq/L, milliequivalents per liter]

Geologic unit	Map symbol (see fig. 23)	Exposure in subarea (acres)	Typical dissolved solids	Typical water type	Water-quality problems
Alluvium	Qal	5,000	Between 1,120 and 3,620 mg/L; median 2,150 mg/L; less than 1,000 mg/L in some side canyons.	Sodium chloride; meq/L of sulfate greater than meq/L of bicarbonate.	Dissolved solids, chloride, sulfate, and occasionally nitrate.
Marine terrace deposits	Qt	3,170	--	--	--
Partly consolidated marine sedimentary rocks	Tp	2,100	Between 380 and 2,360 mg/L; median 1,200 mg/L; depends on location and depth of perforated interval. Low dissolved solids may be associated with faulting.	Sodium chloride; meq/L of sulfate less than meq/L of bicarbonate.	Dissolved solids, chloride, occasionally sulfate and sodium-adsorption ratio.


117°08'
117°06'
R 2 W
32°36'
32°34'
32°32'
T 18 S
T 19 S
WATER-LEVEL CONTOUR – Shows altitude of water level. Contour interval, 10 feet. Datum is sea level
DEPTH TO WATER, IN FEET
0 – 25
25 – 50
Contact dashed where based on topographic expression, queried where approximate
WELL – Upper number is well number. Middle number is altitude of water level, in feet, above or below sea level. Lower number is depth, in feet, below land surface
3B3
– 4.9
37.0
IMPERIAL BEACH
NESTOR
PACIFIC
OCEAN
NAVAL AIR STATION
NAVAL RESERVATION
SAN DIEGO
Smuggler Gulch
32H2
–1.4
12.9
33J1
–10.2
35.3
34N1
–10.6
35.6
32P7
1.5
5.3
32P4
1.4
5.6
33J5
–0.5
7.8
33L8
–5.4
23.4
33L1
–6.6
25.1
33Q1
–8.1
30.1
5A2
–2.0
14.0
33N3
–6.1
23.9
33Q8
–9.0
5C3
0.4
7.6
33P5
–6.7
14.7
33R6
–8.4
31.0
5C7
0.5
9.1
5G11
–3.0
15.1
4B3
–6.9
27.2
5J1
–3.8
16.8
5K8
–2.0
12.8
5L2
–0.4
6.9
–5.1
42.4
117°08'
117°06'
R 2 W

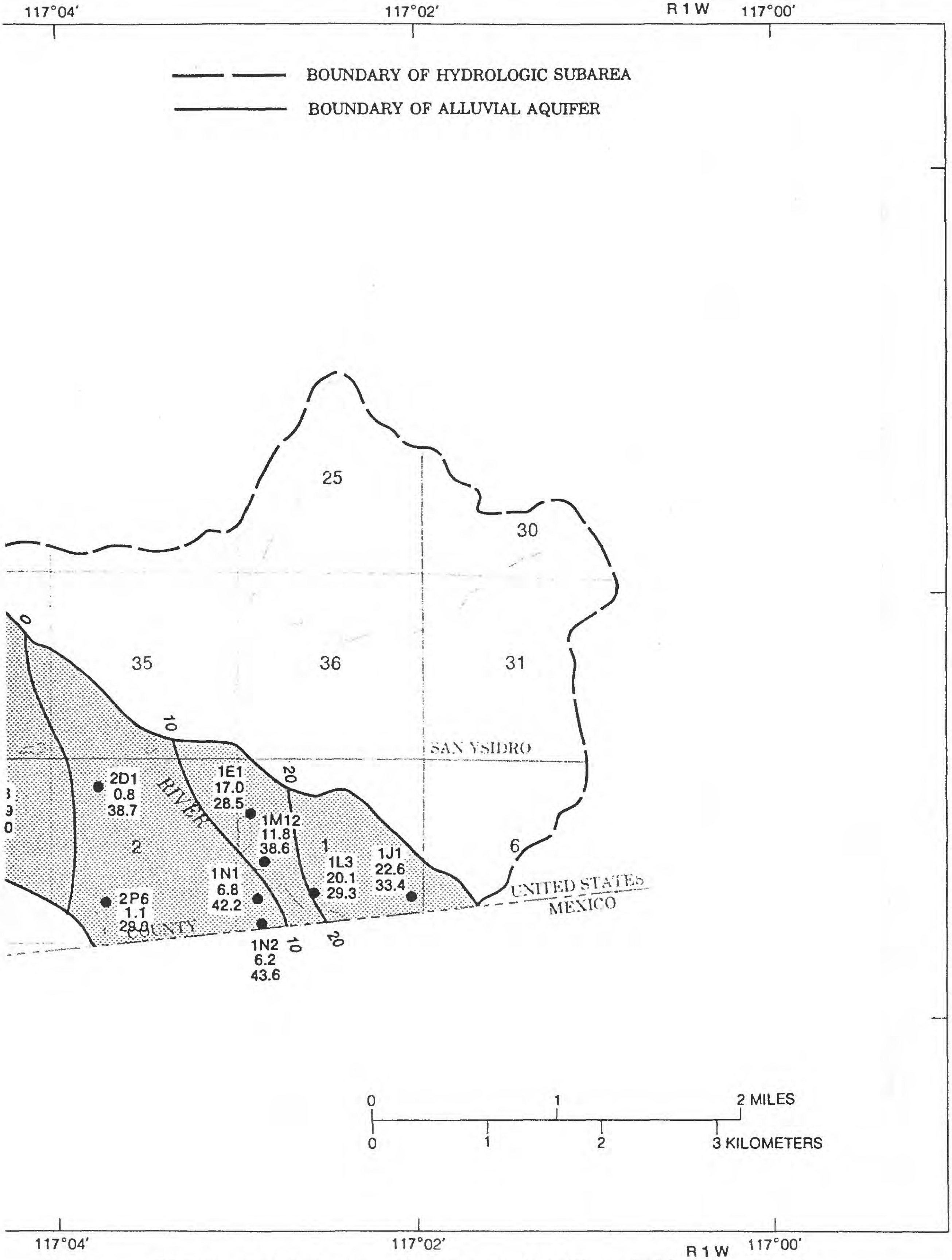
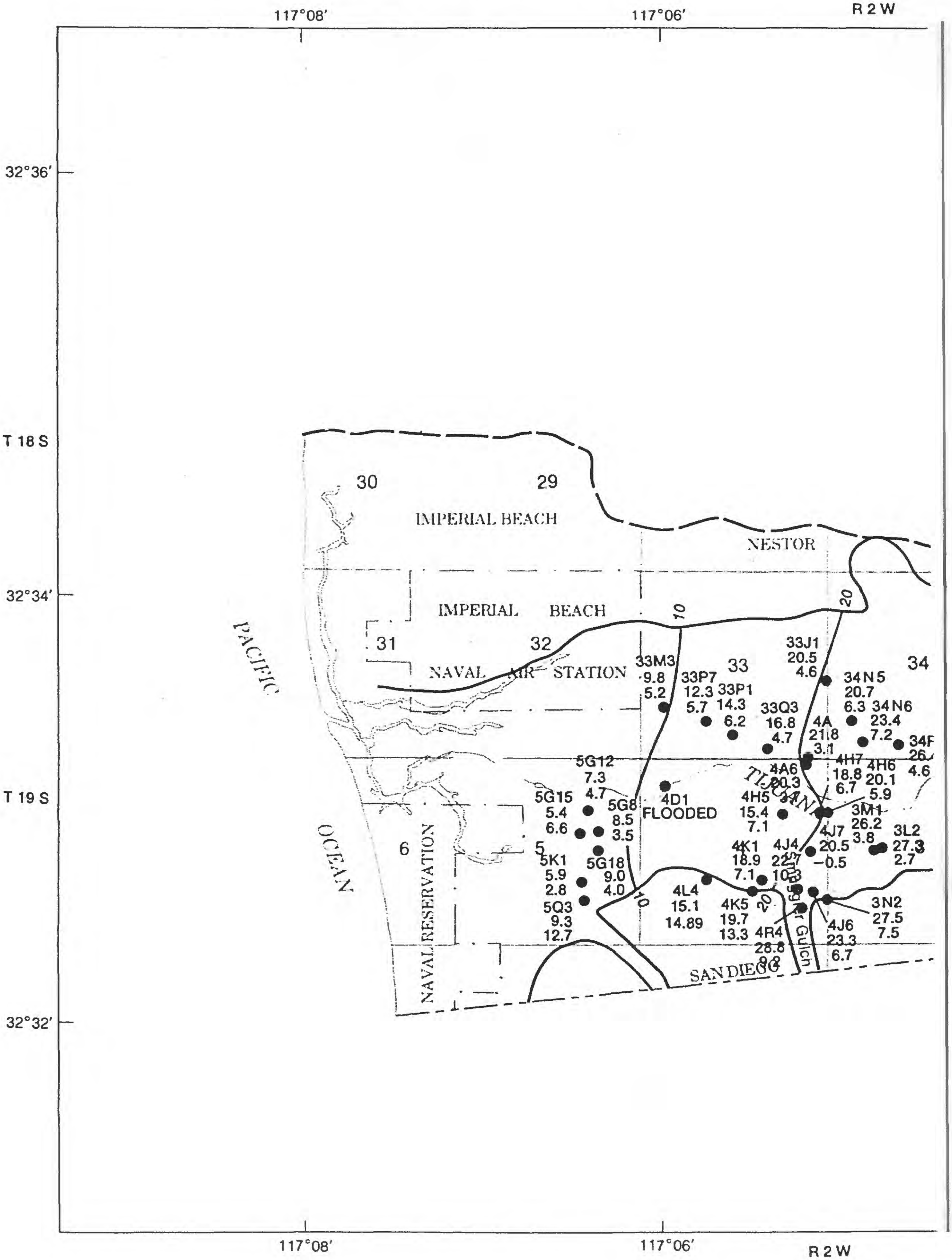


FIGURE 27. - Water-level contours and depth to water in the Tijuana alluvial aquifer, spring 1961.


117°08'
117°06'
R 2 W
32°36'
32°34'
32°32'
T 18 S
T 19 S
IMPERIAL BEACH
NESTOR
IMPERIAL BEACH
NAVAL AIR STATION
PACIFIC
OCEAN
NAVAL RESERVATION
TIJUANA
SAN DIEGO
Smuggler Gulch
4D1
FLOODED

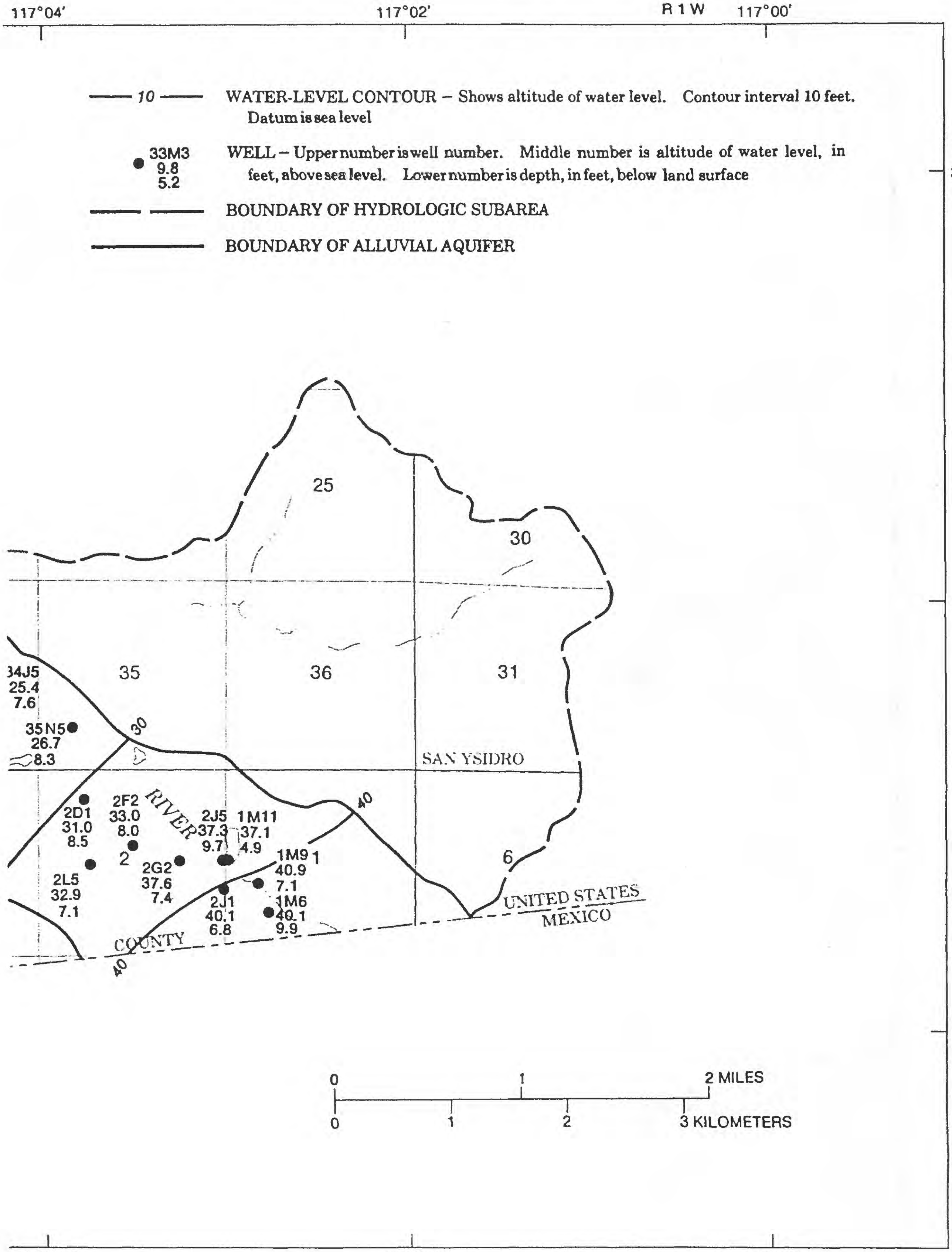


FIGURE 28. - Water-level contours and depth to water in the Tijuana alluvial aquifer, spring 1983.

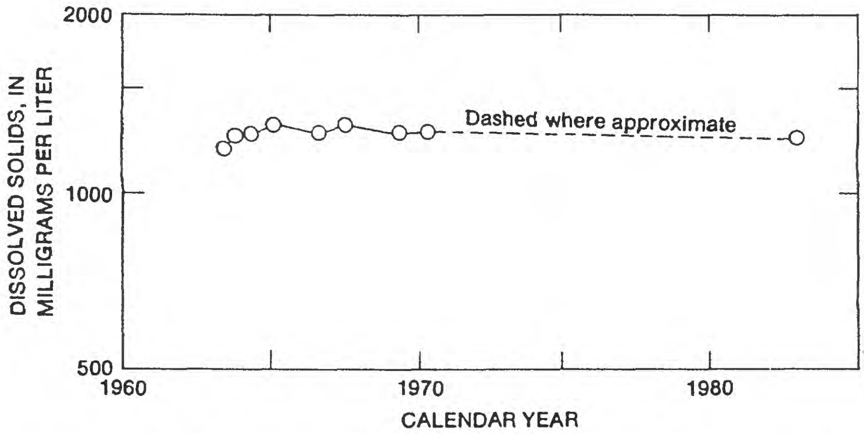


FIGURE 29. - Dissolved solids as a function of time for well 18S/2W—33L10 completed in partly consolidated sediments of the Tijuana hydrologic subarea.

During autumn 1982 and spring 1983, water from four wells completed in partly consolidated sediments was sampled. Dissolved-solids concentrations ranged from 380 to 1,230 mg/L, with a median value of 920 mg/L. Although this was not a representative sampling of ground-water quality, these data indicate that some wells yield water low in dissolved solids. Complete analyses of water from two wells perforated in the partly consolidated sediments (18S/2W-34K1 and 19S/2W-1N6) are summarized in tables 14-15. Both these wells yielded a sodium chloride type water with a sulfate bicarbonate ratio less than 1. Chloride exceeded 250 mg/L in both wells.

Alluvial Aquifer

Historical water quality.--The earliest available ground-water-quality data for the Tijuana subarea were collected in June 1915 by Ellis and Lee (1919). At that time a well completed in the alluvial aquifer near section 18S/2W-32N, less than 1 mile from the Pacific Ocean, yielded water with a dissolved-solids concentration of 730 mg/L. By 1936, seawater intrusion in the alluvial aquifer was a problem, and the California Department of Public Works (1951) began monitoring ground-water quality. Changes in dissolved-solids concentration of ground water with time are shown on semilogarithmic plots in figure 30. Without exception, dissolved-solids concentrations increased. While dissolved-solids concentration of water in the alluvial aquifer increased with time, the dissolved solids of water in the underlying sediments remained almost unchanged (compare fig. 29 with fig. 30).

Changes in ground-water chemistry with time are also apparent. Figure 30 shows the position of the sodium chloride water front associated with seawater intrusion in 1953. A second front of sodium chloride water farther inland was the result of leakage of sodium chloride water from the underlying sediments, irrigation return, and ground-water movement from beyond the international boundary. A small body of ground water of mixed chemical type separated the two fronts of sodium chloride water.

The position of the sodium chloride water front also is shown for 1958, 1961, and 1965. By 1965, mixed ground water had disappeared entirely. On the basis of this analysis, it is apparent that seawater intrusion extended 2 miles inland and was responsible for increases in dissolved solids in that part of the aquifer. Changes in water chemistry in the remainder of the aquifer were the result of leakage of sodium chloride water from the San Diego Formation, sewage disposal by the community of San Ysidro, irrigation return, and ground-water movement from beyond the international boundary.

Present water quality.--During autumn 1982 and spring 1983, water in the alluvial aquifer was sodium chloride in chemical character, and sulfate, in milligrams per liter, exceeded bicarbonate in all wells sampled. Dissolved-solids concentrations exceeded the basin objective of 2,500 mg/L in 3 of 15 wells sampled and ranged as high as 3,620 mg/L (fig. 31).

Field measurements of specific conductance were converted to dissolved-solids concentration using the following relation:

$$DS = 0.71\ SC - 230$$

where

DS is dissolved-solids concentration, in milligrams per liter; and

SC is specific conductance, in micromhos per centimeter at 25°C.

This relation was developed, with data collected by the U.S. Geological Survey during autumn 1982 and spring 1983, using linear regression. Twelve samples with dissolved-solids concentrations ranging from 924 to 3,420 mg/L were used and an R^2 of 0.98 was obtained. This relation is basin specific and care should be used when extrapolating to other areas.

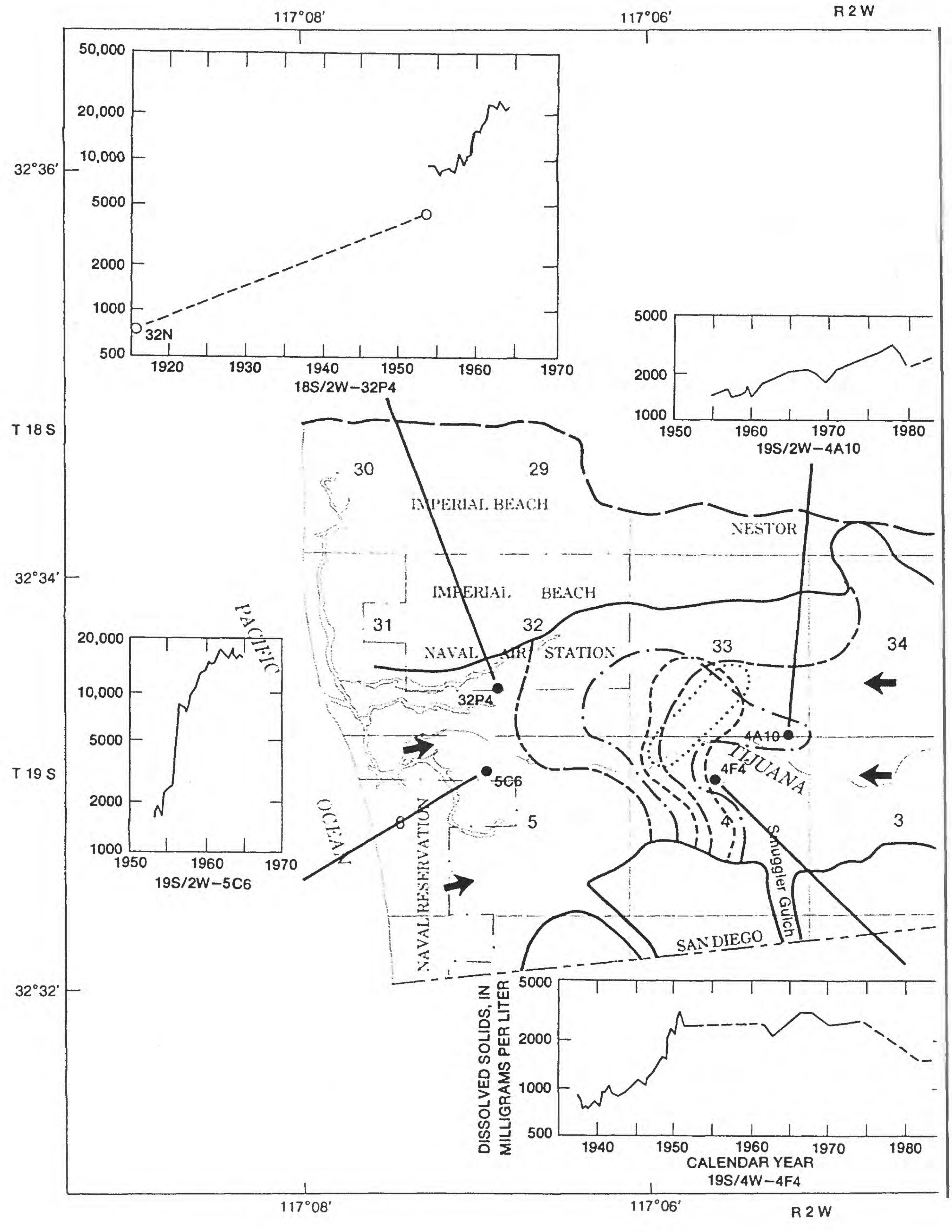
One well in Smuggler Gulch, 19S/2W-4R4, yielded water with a specific conductance of 1,150 µmho/cm. This represents an estimated dissolved-solids concentration of 586 mg/L and is the lowest measured in the alluvial aquifer. Lower dissolved-solids water in and downgradient from the Smuggler Gulch area may be associated with faulting.

Reclaimed-Water Use

At present, reclaimed-water-use plans have not been developed for the Tijuana subarea. Although actual effects will depend greatly on the reclaimed-water-management plan ultimately adopted, it is possible to make general statements concerning the effect of reclaimed-water use on water quality and quantity. To be properly evaluated, effects should be compared to and contrasted with possible future trends in water quality and quantity.

Seawater intrusion, leakage of ground water from surrounding marine sedimentary rocks, and irrigation return have all contributed to water-quality problems in the alluvial aquifer. Because only small quantities of ground water are pumped from the alluvial aquifer, seawater intrusion or leakage of ground water from surrounding marine sedimentary rocks is not likely to be as severe as in the past--even during dry periods.

As a result of current wet conditions, high-quality recharge water is available as stormflow in the Tijuana River. However, ground-water levels are near land surface and much potential recharge is lost as streamflow to the Pacific Ocean. If current wet conditions continue, ground-water quality in the alluvial aquifer is likely to improve slightly in the future. If conditions become dryer as in past years, water levels in the alluvial aquifer may decline, but only limited recharge of questionable quality will be available and ground-water quality may remain poor.



117°08'
117°06'
R 2 W
32°36'
32°34'
32°32'
T 18 S
T 19 S
50,000
20,000
10,000
5000
2000
1000
500
1920
1930
1940
1950
1960
1970
32N
18S/2W–32P4
5000
2000
1000
1950
1960
1970
1980
19S/2W–4A10
20,000
10,000
5000
2000
1000
1950
1960
1970
19S/2W–5C6
30
29
31
32
33
34
6
5
4
3
IMPERIAL BEACH
NESTOR
IMPERIAL BEACH
NAVAL AIR STATION
PACIFIC
OCEAN
NAVAL RESERVATION
TIJUANA
Smuggler Gulch
SAN DIEGO
32P4
5C6
4A10
4F4
DISSOLVED SOLIDS, IN MILLIGRAMS PER LITER
5000
2000
1000
500
1940
1950
1960
1970
1980
CALENDAR YEAR
19S/4W–4F4
117°08'
117°06'
R 2 W

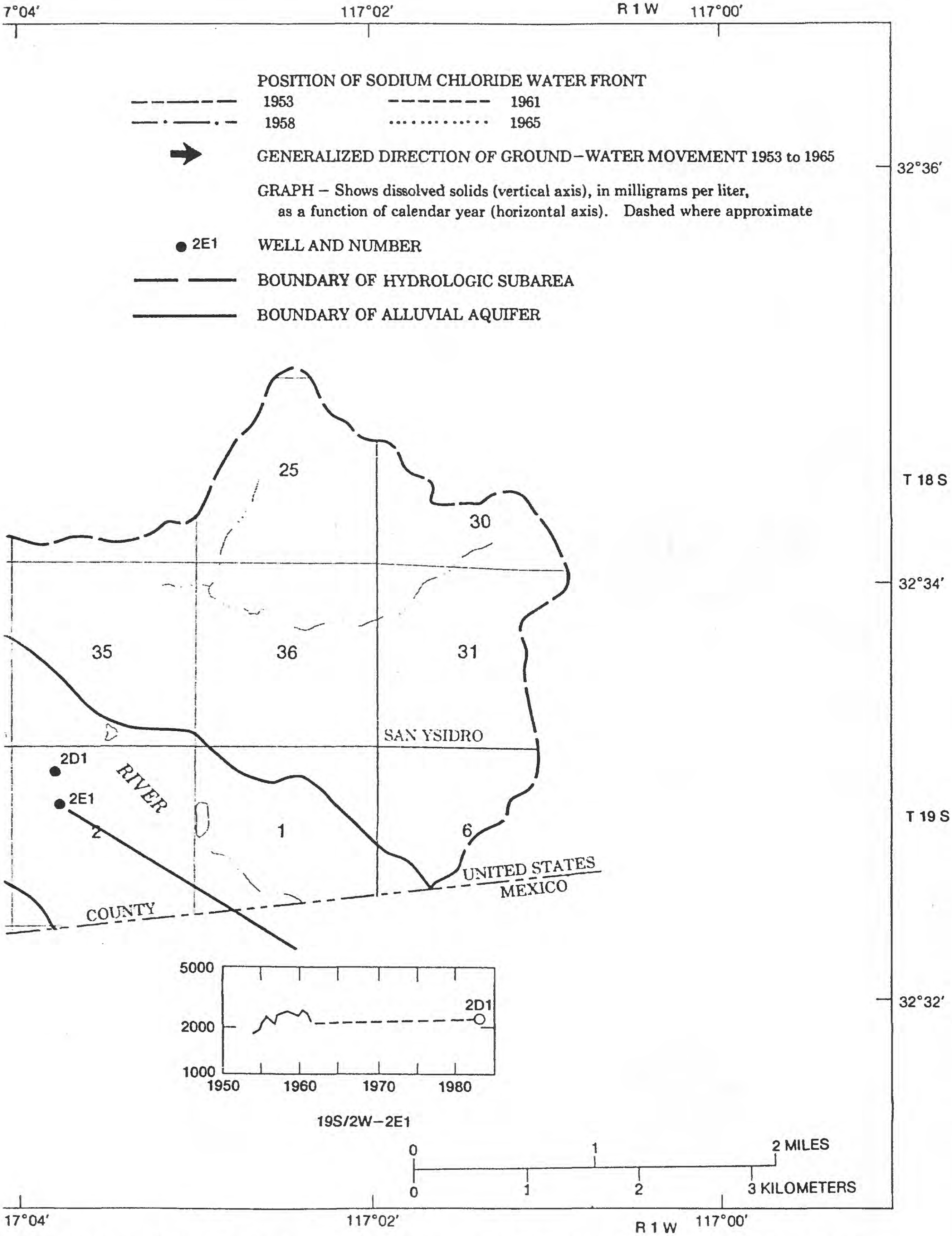
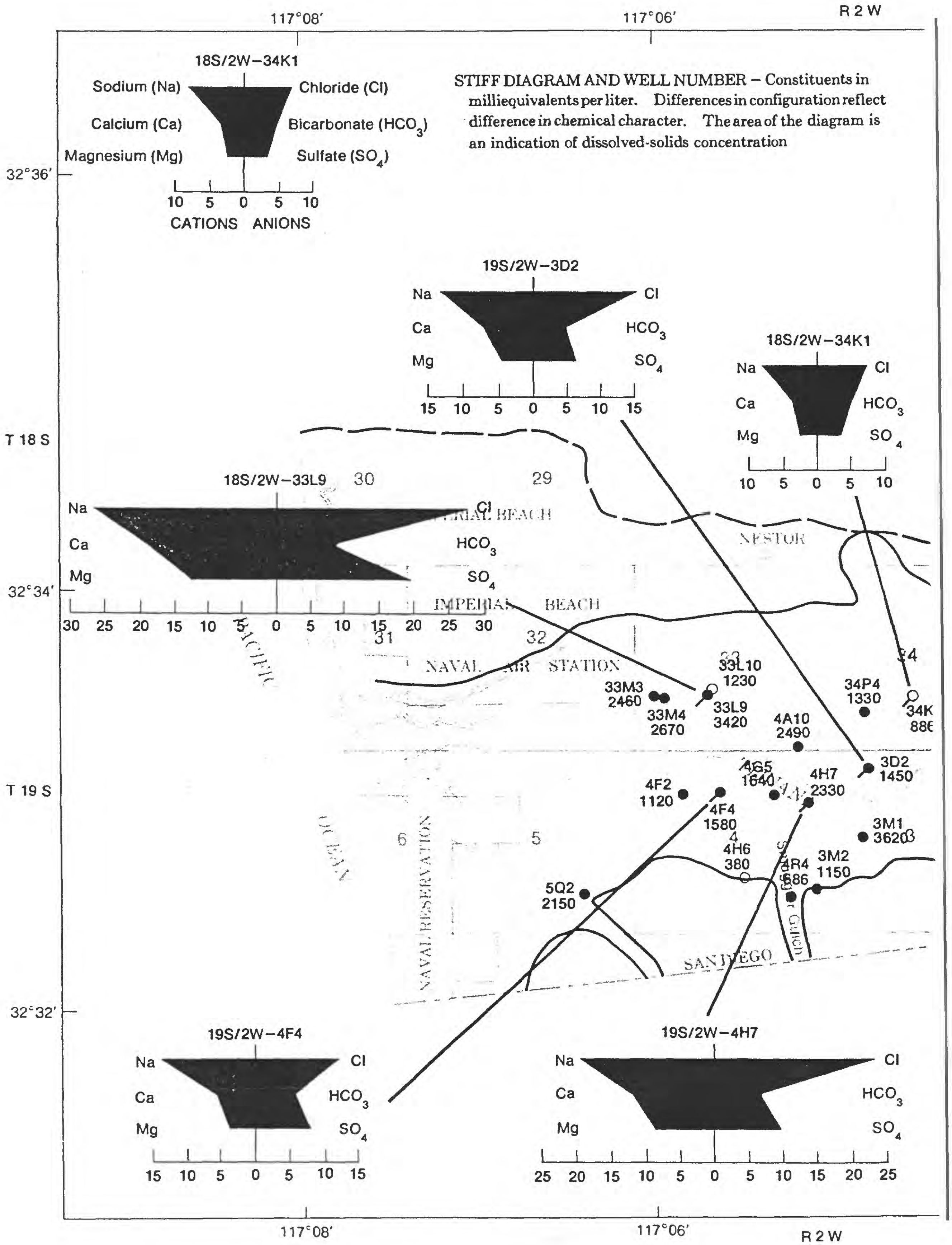


FIGURE 30. - Changes in dissolved-solids concentrations and water type with time at selected wells in the Tijuana alluvial aquifer.



117°08'
117°06'
R 2 W
18S/2W-34K1
Sodium (Na)
Chloride (Cl)
Calcium (Ca)
Bicarbonate (HCO_3)
Magnesium (Mg)
Sulfate (SO_4)
10 5 0 5 10
CATIONS ANIONS
STIFF DIAGRAM AND WELL NUMBER – Constituents in milliequivalents per liter. Differences in configuration reflect difference in chemical character. The area of the diagram is an indication of dissolved-solids concentration
32°36'
19S/2W-3D2
Na Ca Mg
Cl HCO_3 SO_4
15 10 5 0 5 10 15
18S/2W-34K1
10 5 0 5 10
T 18 S
18S/2W-33L9
30 25 20 15 10 5 0 5 10 15 20 25 30
30
29
NESTOR
IMPERIAL BEACH
32°34'
31
32
NAVAL AIR STATION
33L10 1230
33M3 2460
33M4 2670
33L9 3420
34P4 1330
34K 886
4A10 2490
3D2 1450
4G5 1640
4H7 2330
T 19 S
4F2 1120
4F4 1580
4H6 380
3M1 3620
3M2 1150
4R4 586
5Q2 2150
6
5
NAVAL RESERVATION
SAN DIEGO
32°32'
19S/2W-4F4
15 10 5 0 5 10 15
19S/2W-4H7
25 20 15 10 5 0 5 10 15 20 25
117°08'
117°06'
R 2 W

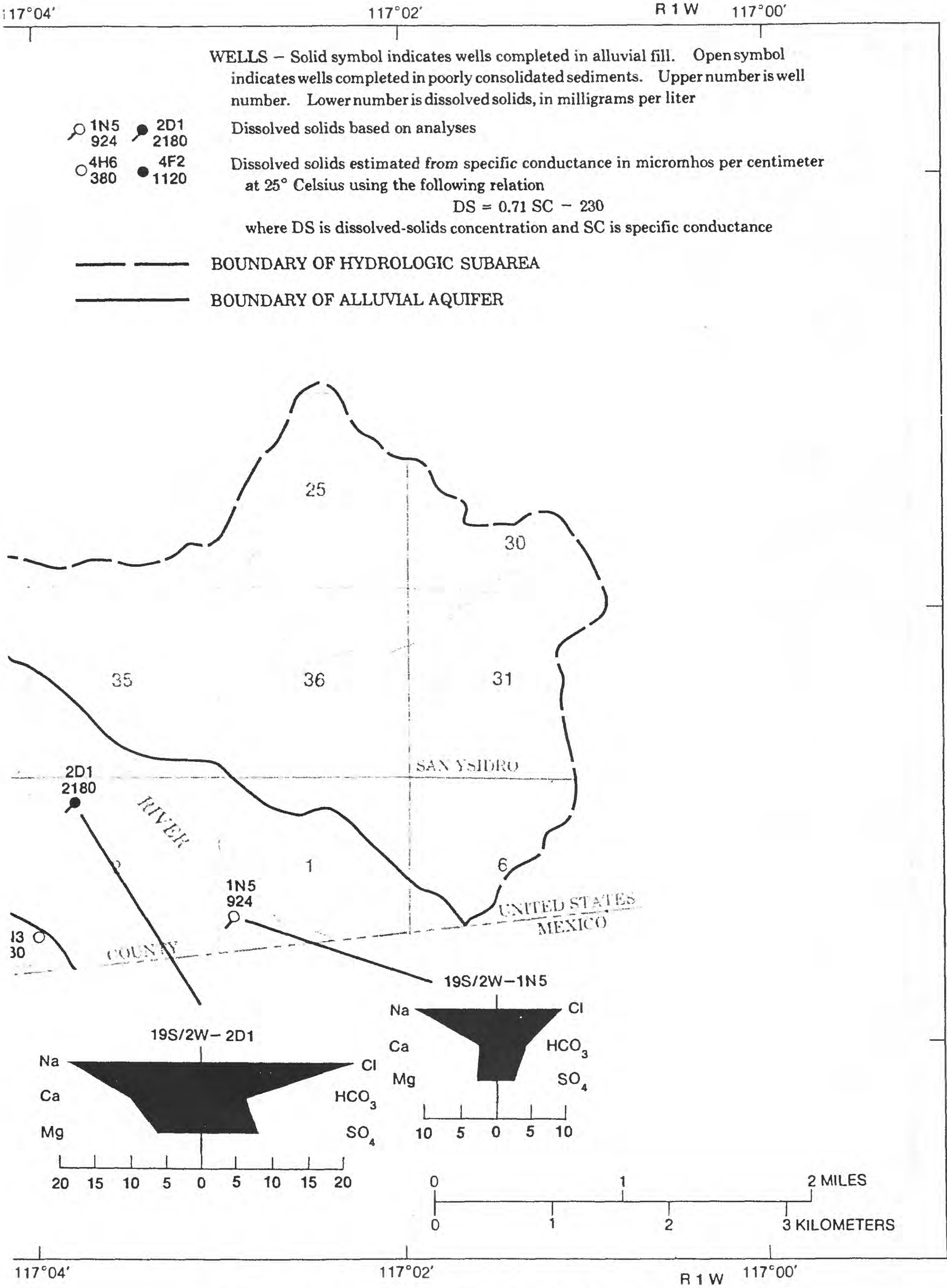


FIGURE 31. - Water quality in the Tijuana hydrologic subarea, spring 1983.

Reclaimed-Water Quality

Reclaimed water used in this subarea would be treated sewage effluent from the city of San Diego Aquaculture Wastewater Treatment Plant. Reclaimed-water quality from this plant is discussed in the section on the Santee subarea and summarized in tables 14-15. Additional water-quality data are available from the city of San Diego Water Utilities Department (1983).

Effects of Reclaimed-Water Use

If reclaimed water is used solely as a replacement for irrigation with imported water, there probably will not be much effect on ground-water quality. At present, only small areas are irrigated with imported water. Locally, irrigation return would increase in dissolved solids, chloride, sulfate, and other dissolved constituents. The increase will be proportional to the difference in quality between present irrigation supplies and the reclaimed water.

If reclaimed water is used as a new source of water supply to develop vacant lands in the valley floor and upland slopes, highly mineralized irrigation-return water could become a major source of recharge to the alluvial aquifer. As a consequence, ground-water quality may deteriorate further; but because ground-water quality is already so poor, this concern may be of little practical importance. Currently, there is no ground-water storage available for reclaimed water in the alluvial aquifer. Use of large quantities of reclaimed water in the Tijuana subarea may contribute to increased waterlogging and surface runoff of reclaimed water. In some upland areas, if reclaimed water is to have adequate soil contact before discharging at land surface, special irrigation techniques and limited application rates may be required. Application rates, volumes, and techniques will have to be evaluated on a site-specific basis.

Reclaimed-water-use plans aimed at improving ground-water quality by pumping highly mineralized water from the subarea and replacing it with reclaimed water of higher quality may be feasible. Similar plans have been proposed by the San Diego County Water Authority for the San Dieguito subarea (Izbicki, 1983). As in the San Dieguito subarea, controlling seawater intrusion and leakage of ground water from surrounding marine sedimentary rocks are the major technical challenges. High-quality stormflow water in the Tijuana River may help achieve basin water-quality objectives, partly compensating for the leakage of ground water from surrounding marine sedimentary rocks. Seawater intrusion will have to be controlled.

SUMMARY

The Mission hydrologic subarea is 43 mi^2 in area and contains an alluvial aquifer that has a maximum ground-water storage capacity of 92,000 acre-ft. In spring 1983, the aquifer was filled to near capacity, and water levels in wells ranged from above land surface to 19.9 feet below land surface. Recharge is primarily from agricultural return from irrigation with imported water in upland areas. Many wells and springs in upland areas flow year round. During 1969-83, ground-water discharge maintained year-round base flow in the San Luis Rey River; prior to 1965, the river was ephemeral and in many years did not flow at all.

Water quality in the alluvial aquifer has been affected by irrigation return and to some degree by seawater intrusion. Ground water was a mixed to sodium chloride water type. Dissolved-solids concentrations ranged from 960 to 3,090 mg/L; the median concentration was 1,220 mg/L. Chloride and sulfate exceed U.S. Environmental Protection Agency recommended limits of 250 mg/L throughout the alluvial aquifer. Ground-water quality in upland areas also has been affected by irrigation return, and dissolved solids, chloride, sulfate, and nitrate may be water-quality problems. Changes in ground-water quality in the alluvial aquifer with time and in surface-water quality in the San Luis Rey River at different flow regimes have been observed.

Reclaimed water is available as secondary-treated sewage effluent from the Oceanside Wastewater Treatment Plant. In general, reclaimed water has lower concentrations of dissolved solids, chloride, and sulfate than existing ground-water supplies.

The Santee hydrologic subarea is 77 mi^2 in area and contains an alluvial aquifer that has a maximum ground-water storage capacity of 55,000 acre-ft. In spring 1983, the aquifer was filled to capacity, and water levels in wells ranged from 2.6 to 25 feet below land surface. Natural recharge has been greatly altered by construction of water-supply reservoirs upstream of the alluvial aquifer. In the 30-year period 1948-78, significant recharge did not occur from the San Diego River or San Vicente Creek. Ground-water levels rose to present level after a series of set years beginning in 1978. Ground-water discharge maintains base flow in the San Diego River near Santee. The median number of days per year with flow greater than 0.1 ft^3/s was 278.

Water quality in the alluvial aquifer has been affected by changes in natural recharge and land use. In spring 1983, water type was mixed ion in the eastern part of the aquifer and mixed cation-chloride in the western part. Dissolved solids west of Moreno Valley generally exceeded 1,000 mg/L, and were as high as 2,990 mg/L. Chloride and sulfate generally exceeded 250 mg/L. Wells near the San Diego River yielded water lower in dissolved solids, chloride, and sulfate. East of Moreno Valley, dissolved solids were generally less than 1,000 mg/L. Dissolved-solids, chloride, and sulfate concentrations were greater downgradient from certain land uses. Nitrates was a problem in some wells throughout the alluvial aquifer. Dissolved solids, chloride, sulfate, and nitrate were local ground-water-quality problems in upland areas.

Treated sewage effluent from the city of San Diego Aquaculture Wastewater Treatment Plant has been proposed for use as reclaimed water. In general, reclaimed water is of higher quality than much of the ground water in the Santee subarea.

The Tijuana subarea is 16 mi^2 in area and contains the lower part of a small alluvial aquifer which extends across the border into Mexico. The part of the aquifer in the United States contains between 50,000 and 80,000 acre-ft of ground water in storage, and the entire aquifer contains 137,000 acre-ft of ground water. In spring 1983, the aquifer was filled to capacity, and water levels in wells ranged from above land surface to 14.89 feet below land surface. Water levels rose as much as 7 feet in response to the wet winter of 1982-83 and high streamflows. Recharge is provided primarily by surface flow in the Tijuana River. Typically, the Tijuana River near Nestor flows only 16 days per year (median number of days with flow greater than 0.1 ft^3/s). In 1983, the Tijuana River flowed all year.

Water quality in the alluvial aquifer has been affected by seawater intrusion, leakage of sodium-chloride water from underlying sediments, irrigation return, and movement of ground water from beyond the international border. In spring 1983, ground water was a sodium chloride type. Dissolved-solids concentrations generally exceeded the basin objective of 1,000 mg/L, and were as high as 3,620 mg/L. Wells in side canyons may yield water with dissolved solids less than 1,000 mg/L. Chloride and sulfate exceeded 250 mg/L in all wells sampled. Changes in ground-water quality with time were observed.

Deep wells in the Tijuana subarea yield water from partly consolidated marine sedimentary rocks. Some of these wells may yield as much as 1,000 gal/min. Water is a sodium chloride type. Dissolved-solids concentrations range from 380 to 2,360 mg/L; the median concentration was 1,220 mg/L. Dissolved-solids concentrations less than 1,000 mg/L may be associated with faulting. Chloride and occasionally sulfate and sodium-adsorption ratio are water-quality problems in the partly consolidated marine sedimentary rocks.

Reclaimed water from the city of San Diego Aquaculture Wastewater Treatment Plant may be available for reuse in the Tijuana subarea.

CONCLUSIONS

Reclaimed water could be used to augment water supplies in the San Diego area. All three subareas have potential for use of reclaimed water as a replacement for imported water, or as an entirely new source of supply. Because alluvial aquifers are full, saturated soils and surface runoff of reclaimed water are potential problems. Application rates and volumes would have to be adjusted accordingly. During dry cycles, water levels in the Santee and Tijuana subareas are likely to decline, lessening concerns about saturated soils and surface runoff of reclaimed water. Because of the large quantity of irrigation return from imported water, water levels are likely to remain near land surface in the Mission alluvial aquifer, even during extended droughts. In upland areas soils are less permeable. Special application techniques along with limited application rates and volumes may be required if reclaimed water is to have adequate soil contact before discharging at land surface.

Reclaimed water could be used to improve ground-water quality in the western part of the Santee and the Tijuana subareas through conjunctive use of local ground-water, surface-water, and reclaimed-water supplies. Reclaimed-water use may be undesirable in the eastern part of the Santee subarea where ground water is used for domestic water supply. Irrigation return has become a significant source of recharge to the Mission subarea and presents a major obstacle to reclaimed-water-use plans aimed at improving ground-water quality.

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TABLE 14. - Ground-water quality data

LOCAL IDENT-I-FIER	DATE OF SAMPLE	TIME	SAM-PLING DEPTH (FEET)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
010S004W33G02S	83-04-18	1030	60.0	1720	7.6	21.5	440	170	93	51
010S004W35B01S	83-04-18	1300	--	2680	7.5	20.5	690	470	120	96
010S004W35R02S	82-11-17	0800	80.0	2270	7.1	17.5	720	480	150	83
	83-05-20	1330	--	2340	7.0	20.5	720	450	160	79
011S004W04Q02S	83-03-09	1000	--	1860	7.5	19.0	650	470	140	74
011S004W08E01S	82-11-17	1100	--	2050	7.5	18.0	680	470	160	67
	83-03-09	1230	--	2150	7.3	19.0	730	550	180	69
011S004W18C09S	82-11-17	1235	--	2190	7.3	19.0	570	320	140	53
011S004W18K01S	83-05-20	1115	100	2730	7.3	20.0	790	490	200	71
011S005W13F01S	82-11-17	1330	--	2590	7.6	20.0	610	350	100	88
	83-03-09	1530	--	2530	7.5	20.0	600	340	100	86
012S001W32M03S	83-06-01	1530	--	1660	7.2	--	590	340	130	65
015S001E18C01S	82-12-02	1000	85.0	2760	7.2	21.5	740	490	150	88
	83-05-19	1500	85.0	2550	7.0	21.5	730	470	150	86
015S001W01J01S	82-12-02	1400	--	780	7.1	20.0	200	77	41	23
	83-05-19	1030	--	820	7.2	20.0	200	74	42	24
015S001W22G02S	82-12-01	1000	60.0	3170	7.9	19.5	940	640	180	120
015S001W28R05S	83-06-01	1200	--	2660	7.7	21.5	710	520	140	87
015S001W29L01S	82-12-01	1400	60.0	4600	7.1	22.0	1700	1400	390	180
	83-05-20	0830	60.0	4750	7.1	22.0	1700	1400	390	180
018S002W33L09S	82-11-16	1400	90.0	4990	7.3	22.0	1400	950	300	150
	83-03-16	1100	90.0	5020	7.4	5.0	1500	1100	370	150
018S002W34K01S	82-11-15	1500	240	1470	8.0	21.0	320	0	78	31
019S002W01N05S	82-11-15	1200	--	1650	8.0	23.0	280	75	53	37
	83-03-15	1700	--	1600	7.9	--	280	63	54	36
019S002W02D01S	83-05-13	1130	102	3650	7.6	19.5	830	520	200	80
019S002W03D02S	82-11-16	1055	87.0	2640	7.6	19.5	610	360	150	56
	83-05-13	0830	87.0	2610	7.6	19.5	620	360	150	60
019S002W04G05S	82-11-16	1130	80.0	2600	7.6	20.5	640	310	150	65
019S002W04H07S	83-03-17	0800	80.0	3750	7.4	20.5	1000	660	240	100

LOCAL IDENT-I-FIER	DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)
010S004W33G02S	83-04-18	190	48	4	3.2	270	83	340	.50	32
010S004W35B01S	83-04-18	260	45	4	6.2	230	340	520	.50	42
010S004W35R02S	82-11-17	210	39	4	7.1	240	360	390	.30	22
	83-05-20	200	37	3	8.6	280	390	380	.20	17
011S004W04Q02S	83-03-09	160	34	3	7.2	190	350	320	.40	26
011S004W08E01S	82-11-17	180	36	3	7.7	210	360	350	.30	24
	83-03-09	180	34	3	8.2	180	400	370	.30	26
011S004W18C09S	82-11-17	250	48	5	8.2	250	290	410	.30	29
011S004W18K01S	83-05-20	260	41	4	9.0	300	360	500	.20	27
011S005W13F01S	82-11-17	310	52	6	5.9	--	150	630	.70	31
	83-03-09	310	52	6	6.0	260	150	620	.70	29
012S001W32M03S	83-06-01	120	30	2	3.1	250	350	190	.30	40
015S001E18C01S	82-12-02	280	45	5	3.5	250	490	380	.50	50
	83-05-19	260	44	4	3.5	260	520	350	.50	48
015S001W01J01S	82-12-02	82	47	3	1.4	120	130	81	.40	35
	83-05-19	84	47	3	1.5	130	130	90	.40	36
015S001W22G02S	82-12-01	310	42	5	2.7	300	130	770	.70	86
015S001W28R05S	83-06-01	240	42	4	6.1	190	120	650	.30	32
015S001W29L01S	82-12-01	320	29	3	6.3	280	200	1300	.30	41
	83-05-20	330	29	4	6.5	290	200	1300	.30	38
018S002W33L09S	82-11-16	670	51	8	22	420	860	1100	.60	27
	83-03-16	610	46	7	19	400	920	990	.60	24
018S002W34K01S	82-11-15	200	57	5	4.7	350	150	250	.90	18
019S002W01N05S	82-11-15	240	64	6	7.4	210	120	350	.40	23
	83-03-15	240	64	6	7.6	220	120	340	.40	25
019S002W02D01S	83-05-13	430	53	7	5.7	310	380	720	.70	19
019S002W03D02S	82-11-16	310	53	6	3.8	250	290	510	.80	20
	83-05-13	310	52	6	4.0	260	290	520	.80	18
019S002W04G05S	82-11-16	360	55	6	4.1	330	410	470	.80	15
019S002W04H07S	83-03-17	450	49	6	5.0	350	440	860	.60	20

TABLE 14. - Ground-water quality data - Continued

LOCAL IDENT-I-FIER	DATE OF SAMPLE	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, ORGANIC DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)
010S004W33G02S	83-04-18	1020	960	--	<.020	7.1	.080	.42	.50	.070
010S004W35B01S	83-04-18	1760	1500	--	<.020	12	.060	1.5	1.6	.090
010S004W35R02S	82-11-17	1410	1400	2.8	.170	3.0	<.060	--	1.5	.030
	83-05-20	1420	1400	1.3	.080	1.4	<.060	--	1.3	.020
011S004W04Q02S	83-03-09	1220	1200	--	<.020	.18	.090	.31	.40	.140
011S004W08E01S	82-11-17	1300	1300	--	<.020	.91	.240	.96	1.2	.030
	83-03-09	1410	1300	--	<.020	1.1	.160	.34	.50	.060
011S004W18C09S	82-11-17	1350	1300	--	<.020	<.10	.230	.67	.90	.020
011S004W18K01S	83-05-20	1540	1600	--	<.020	<.10	.100	.90	1.0	.010
011S005W13F01S	82-11-17	1500	1500	1.9	.050	1.9	<.060	--	.90	.040
	83-03-09	1500	1500	1.5	.060	1.6	.110	.69	.80	.030
012S001W32M03S	83-06-01	1090	1100	.58	.020	.60	.150	.85	1.0	.080
015S001E18C01S	82-12-02	1630	1700	17	.190	17	.080	1.7	1.8	.070
	83-05-19	1630	1600	15	.090	15	<.060	--	.60	.100
015S001W01J01S	82-12-02	492	470	--	<.200	6.7	<.060	--	1.5	.030
	83-05-19	485	490	--	<.020	5.7	<.060	--	1.3	.050
015S001W22G02S	82-12-01	1850	1800	--	<.010	6.5	<.060	--	1.3	.110
015S001W28R05S	83-06-01	1620	1400	9.7	.030	9.7	3.00	1.0	4.0	.040
015S001W29L01S	82-12-01	2890	2600	--	<.020	40	.080	1.7	1.8	.050
	83-05-20	2870	2600	--	<.020	40	.090	1.0	1.1	.060
018S002W33L09S	82-11-16	3380	3500	17	.110	17	.120	1.8	1.9	.250
	83-03-16	3420	3400	14	.110	14	.140	.76	.90	.160
018S002W34K01S	82-11-15	886	950	.75	.040	.79	<.060	--	1.0	.080
019S002W01N05S	82-11-15	951	960	--	<.020	<.10	.170	.43	.60	<.010
	83-03-15	924	960	--	<.020	<.10	.170	.23	.40	.030
019S002W02D01S	83-05-13	2180	2100	22	.120	22	.100	1.1	1.2	.060
019S002W03D02S	82-11-16	1530	1500	3.9	.050	3.9	<.060	--	1.6	.080
	83-05-13	1450	1500	5.3	.040	5.3	.080	1.1	1.2	.080
019S002W04G05S	82-11-16	1640	1700	12	.130	12	<.060	--	2.1	.060
019S002W04H07S	83-03-17	3410	2300	--	<.020	<.10	.170	.43	.60	.050

LOCAL IDENT-I-FIER	DATE OF SAMPLE	ALUM-INUM, DIS-SOLVED (UG/L AS AL)	ANTI-MONY, DIS-SOLVED (UG/L AS SB)	ARSENIC DIS-SOLVED (UG/L AS AS)	BARIUM, DIS-SOLVED (UG/L AS BA)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM DIS-SOLVED (UG/L AS CD)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COBALT, DIS-SOLVED (UG/L AS CO)
010S004W33G02S	83-04-18	--	--	--	--	--	220	--	--	--
010S004W35B01S	83-04-18	--	--	--	--	--	250	--	--	--
010S004W35R02S	82-11-17	--	--	--	--	--	200	--	--	--
	83-05-20	10	--	--	--	--	200	--	--	--
	83-03-09	--	--	--	--	--	150	--	--	--
011S004W08E01S	82-11-17	--	--	--	--	--	130	--	--	--
	83-03-09	--	--	--	--	--	130	--	--	--
011S004W18C09S	82-11-17	10	<1	1	<100	<10	300	<1	<10	1
011S004W18K01S	83-05-20	<10	--	--	--	--	250	--	--	--
011S005W13F01S	82-11-17	--	--	--	--	--	380	--	--	--
	83-03-09	--	--	--	--	--	380	--	--	--
012S001W32M03S	83-06-01	--	--	--	--	--	90	--	--	--
015S001E18C01S	82-12-02	10	<1	1	<100	<10	230	<1	<10	2
	83-05-19	<10	--	--	--	--	250	--	--	--
015S001W01J01S	82-12-02	--	--	--	--	--	80	--	--	--
	83-05-19	--	--	--	--	--	80	--	--	--
015S001W22G02S	82-12-01	--	--	--	--	--	190	--	--	--
015S001W28R05S	83-06-01	20	--	--	--	--	120	--	--	--
015S001W29L01S	82-12-01	20	<1	1	100	<10	170	<1	<10	1
	83-05-20	<10	--	--	--	--	170	--	--	--
018S002W33L09S	82-11-16	--	--	--	--	--	650	--	--	--
	83-03-16	--	--	--	--	--	640	--	--	--
018S002W34K01S	82-11-15	--	--	--	--	--	270	--	--	--
019S002W01N05S	82-11-15	20	<1	<1	48	<.5	300	2	<10	<1
	83-03-15	--	--	--	--	--	300	--	--	--
019S002W02D01S	83-05-13	--	--	--	--	--	570	--	--	--
019S002W03D02S	82-11-16	--	--	--	--	--	310	--	--	--
	83-05-13	--	--	--	--	--	320	--	--	--
019S002W04G05S	82-11-16	10	1	1	<100	<10	470	<1	<10	<1
019S002W04H07S	83-03-17	--	--	--	--	--	490	--	--	--

TABLE 14. - Ground-water quality data - Continued

LOCAL IDENT-I-FIER	DATE OF SAMPLE	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	MOLYB-DENUM, DIS-SOLVED (UG/L AS MO)	NICKEL, DIS-SOLVED (UG/L AS NI)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	SILVER, DIS-SOLVED (UG/L AS AG)	ZINC, DIS-SOLVED (UG/L AS ZN)
010S004W33G02S	83-04-18	--	22	--	--	--	--	--	--	--
010S004W35B01S	83-04-18	--	30	--	--	--	--	--	--	--
010S004W35R02S	82-11-17	--	50	--	--	--	--	--	--	--
	83-05-20	--	120	--	840	--	--	--	--	--
011S004W04Q02S	83-03-09	--	64	--	--	--	--	--	--	--
011S004W08E01S	82-11-17	--	110	--	--	--	--	--	--	--
	83-03-09	--	40	--	--	--	--	--	--	--
011S004W18C09S	82-11-17	<1	1900	<1	440	7	1	<1	<1	10
011S004W18K01S	83-05-20	--	2000	--	340	--	--	--	--	--
011S005W13F01S	82-11-17	--	90	--	--	--	--	--	--	--
	83-03-09	--	150	--	--	--	--	--	--	--
012S001W32M03S	83-06-01	--	480	--	--	--	--	--	--	--
015S001E18C01S	82-12-02	1	80	<1	1200	11	1	3	<1	560
	83-05-19	--	40	--	1100	--	--	--	--	--
015S001W01J01S	82-12-02	--	33	--	--	--	--	--	--	--
	83-05-19	--	21	--	--	--	--	--	--	--
015S001W22G02S	82-12-01	--	50	--	--	--	--	--	--	--
015S001W28R05S	83-06-01	--	40	--	210	--	--	--	--	--
015S001W29L01S	82-12-01	1	20	<1	10	4	2	5	<1	20
	83-05-20	--	30	--	6	--	--	--	--	--
018S002W33L09S	82-11-16	--	220	--	--	--	--	--	--	--
	83-03-16	--	90	--	--	--	--	--	--	--
018S002W34K01S	82-11-15	--	28	--	--	--	--	--	--	--
019S002W01N05S	82-11-15	<1	20	<1	50	8	1	<1	<1	66
	83-03-15	--	13	--	--	--	--	--	--	--
019S002W02D01S	83-05-13	--	100	--	--	--	--	--	--	--
019S002W03D02S	82-11-16	--	50	--	--	--	--	--	--	--
	83-05-13	--	80	--	--	--	--	--	--	--
019S002W04G05S	82-11-16	2	10	<1	450	21	<1	2	<1	10
019S002W04H07S	83-03-17	--	230	--	--	--	--	--	--	--

TABLE 15. - Reclaimed-water and surface-water quality data

SAN LUIS REY RIVER AT MONSERATE NARROWS

DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
73-04-04	1615	--	1200	7.4	19.0	400	220	100	37
75-02-10	1230	1.0	1750	8.3	17.0	630	420	130	73
75-03-06	1550	1.0	1750	7.8	17.5	600	410	120	72
75-04-22	1330	1.0	2000	--	20.5	650	430	140	72
76-02-12	0940	2.9	2030	7.6	13.0	690	500	140	82
76-03-04	1715	1.0	1840	7.4	12.5	590	410	120	71
77-08-17	1500	--	1920	7.3	22.5	590	440	120	70
78-03-01	1020	100	680	7.8	14.5	150	0	34	15
79-01-31	1015	51	900	7.2	11.0	330	190	84	29
79-06-13	1040	--	1000	7.7	30.0	400	210	100	34
80-05-14	0805	--	730	7.8	15.0	270	--	69	23
81-06-18	1015	5.0	1100	7.8	27.0	400	190	98	38

DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)
73-04-04	95	33	2	15	184	250	120	25	--
75-02-10	160	36	3	6.0	204	360	270	32	--
75-03-06	150	35	3	5.8	191	360	260	24	--
75-04-22	170	36	3	5.4	221	370	290	27	--
76-02-12	170	35	3	6.7	186	440	280	34	--
76-03-04	150	35	3	6.5	182	380	240	31	--
77-08-17	180	40	3	8.0	148	440	270	30	1300
78-03-01	36	25	1	65	197	21	70	15	--
79-01-31	55	25	1	22	140	180	79	26	--
79-06-13	69	27	2	11	190	230	95	34	806
80-05-14	48	27	1	9.4	--	120	78	32	511
81-06-18	84	31	2	12	--	190	140	31	--

DATE OF SAMPLE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, ORGANIC DIS-SOLVED (MG/L AS N)	NITRO-GEN, AM-MONIA + ORGANIC DIS. (MG/L AS N)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)
73-04-04	750	.45	--	--	--	--
75-02-10	1200	.36	--	--	--	--
75-03-06	1100	.05	--	--	--	--
75-04-22	1200	.08	--	--	--	--
76-02-12	1300	5.8	--	--	--	--
76-03-04	1100	3.1	--	--	--	--
77-08-17	1200	--	--	--	--	--
78-03-01	370	.07	--	--	--	--
79-01-31	560	1.3	--	--	--	.700
79-06-13	700	--	--	--	--	--
80-05-14	480	--	--	--	--	--
81-06-18	720	1.0	--	--	--	.170

TABLE 15. - Reclaimed-water and surface-water quality data - Continued

SAN LUIS REY RIVER AT OCEANSIDE

DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
72-05-05	1030	--	2470	7.1	17.0	550	370	130	55
73-04-06	1240	20	2280	7.4	15.5	670	450	150	72
78-01-23	1345	125	2010	8.2	13.5	740	530	160	83
78-02-28	1345	134	1800	--	16.0	600	400	130	66
78-03-16	1230	430	1540	7.3	19.0	540	360	120	59
78-04-25	1245	250	1180	7.9	21.5	500	320	110	54
78-05-25	1000	190	896	8.2	18.0	290	150	68	30
78-06-29	1130	148	892	7.3	21.0	290	150	70	29
78-07-24	1230	15	2470	7.9	25.0	770	540	170	84
78-08-22	1200	2.2	4660	8.0	22.5	970	720	190	120
78-09-07	1045	3.0	2310	7.6	19.5	730	500	160	81
78-10-23	1345	17	2420	8.2	20.5	820	580	180	90
78-11-30	1100	33	2280	8.2	11.0	860	600	180	100
78-12-22	0940	98	2180	7.3	8.0	730	490	160	80
79-01-29	1300	117	2010	8.0	11.0	720	510	170	72
79-02-22	1100	413	1050	7.6	13.0	380	260	83	41
79-03-13	1420	100	1450	8.1	20.0	590	400	130	65
79-04-10	1230	413	850	7.8	18.5	290	160	68	28
79-05-30	1420	55	1700	8.4	26.0	620	400	140	65
79-06-28	1230	11	1970	8.5	--	560	400	110	70
79-07-26	1235	7.2	2000	8.3	33.0	680	480	140	81
79-09-11	1415	6.0	2150	8.4	27.0	650	470	130	80
79-10-17	1400	8.4	2190	8.3	23.0	770	570	150	95
79-11-15	1230	20	2340	8.1	19.0	790	560	160	96
79-12-19	0830	22	2120	8.1	8.0	770	530	160	89
80-01-22	1100	146	1780	8.1	15.0	600	400	130	66
80-02-27	1300	1100	1200	8.5	17.5	320	180	71	35
80-03-26	1145	580	900	7.5	16.5	290	160	65	31
80-04-17	1530	427	840	8.3	26.0	270	140	65	27
80-05-27	1330	342	825	--	20.0	270	140	62	28
80-06-26	1430	272	750	8.1	20.0	250	120	60	24
80-08-20	1030	347	650	8.0	23.0	230	96	54	22
80-09-16	1015	168	850	7.9	21.0	450	250	100	48
80-11-20	1230	50	1720	8.3	14.0	600	360	130	66
81-01-19	1300	51	1620	8.2	21.0	620	400	140	66
81-03-30	1000	84	1670	8.2	21.0	570	370	130	59
81-05-13	1300	26	2100	8.2	24.0	650	420	140	73
81-07-28	1200	7.6	2260	8.2	29.0	800	610	180	86
81-09-28	1100	3.5	2580	8.4	24.0	820	620	180	90
81-11-30	1100	49	1670	8.2	14.5	610	420	130	69
82-01-20	1100	145	1380	8.3	12.5	500	330	110	54
82-03-29	0900	298	1530	8.2	14.5	490	310	110	53
82-05-26	1100	41	1920	8.2	19.5	690	440	150	77
82-07-28	1300	5.4	2510	8.5	31.0	770	560	170	85
82-09-21	1130	12	2150	8.0	23.5	750	550	160	84
82-11-23	1500	30	2090	8.2	17.0	660	450	140	76
83-01-24	1300	69	1840	8.2	15.0	600	400	130	68
83-03-09	1200	639	1070	7.9	19.0	320	190	71	35
83-05-18	1230	247	950	8.3	24.5	300	140	67	31
83-07-19	1300	23	2010	8.5	30.5	640	430	140	71

TABLE 15. - Reclaimed-water and surface-water quality data - Continued

SAN LUIS REY RIVER AT OCEANSIDE - Continued

DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)
72-05-05	290	52	6	16	180	440	400	19	1540
73-04-06	240	43	4	12	218	420	370	18	--
78-01-23	160	32	3	9.4	210	430	290	30	1360
78-02-28	160	37	3	7.0	200	300	310	27	1170
78-03-16	130	34	2	8.3	180	270	240	31	990
78-04-25	110	32	2	7.4	180	260	190	27	905
78-05-25	72	34	2	5.2	140	160	99	18	558
78-06-29	69	33	2	5.5	140	160	100	16	553
78-07-24	260	42	4	11	230	390	480	19	1680
78-08-22	640	58	9	31	250	510	1200	20	3040
78-09-07	220	39	4	13	230	390	390	24	1550
78-10-23	230	38	4	10	240	400	460	21	1630
78-11-30	180	31	3	7.2	260	410	380	29	1540
78-12-22	200	37	3	9.4	240	400	360	28	1420
79-01-29	180	35	3	6.9	210	380	350	30	1560
79-02-22	88	33	2	4.3	120	220	160	24	705
79-03-13	130	32	2	5.2	190	320	230	30	1080
79-04-10	66	33	2	4.4	130	150	100	27	550
79-05-30	150	34	3	6.7	220	330	260	29	1180
79-06-28	180	41	3	4.0	160	360	320	15	965
79-07-26	180	36	3	8.8	200	390	340	28	1500
79-09-11	200	40	3	8.8	180	440	360	27	1420
79-10-17	200	36	3	8.5	200	430	360	28	1460
79-11-15	210	36	3	6.4	240	430	360	33	1470
79-12-19	170	32	3	6.3	240	410	340	40	1400
80-01-22	150	35	3	7.3	200	360	270	33	1180
80-02-27	84	36	2	7.2	140	180	140	40	653
80-03-26	73	35	2	5.9	130	150	120	27	552
80-04-17	63	33	2	6.4	130	150	110	27	518
80-05-27	68	35	2	5.0	130	130	99	27	528
80-06-26	60	34	2	6.2	130	110	80	26	446
80-08-20	54	34	2	5.1	130	100	72	21	394
80-09-16	120	37	3	5.5	200	220	210	28	807
80-11-20	170	38	3	7.4	--	330	300	29	1240
81-01-19	170	37	3	6.9	--	330	280	29	1210
81-03-30	140	35	3	5.7	--	300	260	30	1100
81-05-13	180	37	3	7.4	--	360	320	27	1330
81-07-28	240	39	4	9.2	--	450	440	20	1520
81-09-28	260	41	4	8.6	--	500	480	18	1770
81-11-30	160	36	3	8.6	--	350	300	21	1260
82-01-20	120	34	2	8.4	--	260	230	20	932
82-03-29	130	36	3	6.0	180	280	220	32	1010
82-05-26	180	36	3	7.0	250	380	320	30	1300
82-07-28	260	42	4	9.1	220	450	460	22	1760
82-09-21	230	40	4	8.4	200	420	420	24	1570
82-11-23	190	38	3	6.2	--	390	340	--	1330
83-01-24	160	36	3	6.1	203	350	290	29	1220
83-03-09	89	37	2	5.6	131	180	140	31	670
83-05-18	78	36	2	4.2	153	160	120	30	585
83-07-19	190	39	3	7.6	216	360	330	28	1310

TABLE 15. - Reclaimed-water and surface-water quality data - Continued

SAN LUIS REY RIVER AT OCEANSIDE - Continued

DATE OF SAMPLE	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
72-05-05	1500	7.2	--	--	--	--
73-04-06	1400	3.8	--	--	--	--
78-01-23	1300	--	--	--	--	--
78-02-28	1100	--	--	--	.97	--
78-03-16	970	--	--	--	.66	--
78-04-25	870	--	--	--	.75	--
78-05-25	540	--	--	--	.81	--
78-06-29	530	--	--	--	.58	--
78-07-24	1600	--	--	--	.68	--
78-08-22	2900	--	--	--	.99	--
78-09-07	1400	--	--	--	1.4	--
78-10-23	1500	--	--	--	.98	--
78-11-30	1400	--	--	--	--	--
78-12-22	1400	--	--	--	1.2	--
79-01-29	1300	--	--	--	1.1	--
79-02-22	690	--	--	--	.78	--
79-03-13	1000	--	--	--	.50	--
79-04-10	520	--	--	--	.45	--
79-05-30	1100	--	--	--	.48	--
79-06-28	1200	--	--	--	.11	--
79-07-26	1300	--	--	--	--	--
79-09-11	1400	1.4	--	--	.35	--
79-10-17	1400	1.3	.040	.62	.66	--
79-11-15	1400	1.5	.050	.68	.73	--
79-12-19	1400	1.3	.030	.81	.84	--
80-01-22	1100	2.2	.100	.42	.52	--
80-02-27	640	2.7	.140	1.2	1.3	--
80-03-26	550	1.9	.100	1.7	1.8	--
80-04-17	530	1.6	.080	.92	1.0	--
80-05-27	500	1.4	.000	1.2	1.2	--
80-06-26	440	.88	.000	.30	.30	--
80-08-20	410	.50	.000	.26	.26	--
80-09-16	850	1.5	.100	.78	.88	--
80-11-20	1200	1.8	.160	.84	1.0	--
81-01-19	1200	2.4	.040	.77	.81	--
81-03-30	1000	1.7	.060	.72	.78	--
81-05-13	1200	1.4	.120	.98	1.1	--
81-07-28	1500	3.0	.210	.99	1.2	--
81-09-28	1700	.22	.100	.70	.80	--
81-11-30	1200	2.6	.140	--	--	.220
82-01-20	910	1.4	.450	--	--	.180
82-03-29	940	2.3	.100	--	--	.170
82-05-26	1300	2.3	.100	--	--	.110
82-07-28	1600	.93	.130	--	--	.110
82-09-21	1500	.95	.180	--	--	.070
82-11-23	1300	1.1	.070	--	--	.050
83-01-24	1200	2.0	.090	--	--	.090
83-03-09	630	2.4	.190	--	--	.160
83-05-18	580	1.0	<.060	--	--	.110
83-07-19	1300	1.0	.040	--	--	.100

TABLE 15. - Reclaimed-water and surface-water quality data - Continued

OCEANSIDE WASTEWATER TREATMENT PLANT SECONDARY

DATE OF SAMPLE	TIME	STREAM-FLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (UMHOS)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
83-03-14	--	--	1410	7.8	--	326	--	73	35

DATE OF SAMPLE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)
83-03-14	210	57	5.2	12	265	--	260	18	980

DATE OF SAMPLE	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)	BORON, DISSOLVED (UG/L AS B)	IRON, DISSOLVED (UG/L AS FE)	CARBON, ORGANIC TOTAL (UG/L AS C)
83-03-14	1046	1.8	21	11	32	4.5	570	--	12

SAN DIEGO AQUACULTURE WASTEWATER

DATE OF SAMPLE	TIME	STREAM-FLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (UMHOS)	PH (STANDARD UNITS)	TEMPERATURE (DEG C)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
83-03-14	--	--	1450	7.7	--	312	190	69	34

DATE OF SAMPLE	SODIUM, DISSOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM ADSORPTION RATIO	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY FIELD (MG/L AS CACO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)
83-03-14	180	55	4.5	3.5	128	--	210	26	900

DATE OF SAMPLE	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N)	NITROGEN, ORGANIC DISSOLVED (MG/L AS N)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)	BORON, DISSOLVED (UG/L AS B)	IRON, DISSOLVED (UG/L AS FE)	CARBON, ORGANIC TOTAL (UG/L AS C)
83-03-14	865	13	.160	1.6	1 .8	.810	440	330	14

TABLE 15. - Reclaimed-water and surface-water quality data - Continued

SAN DIEGO RIVER BELOW EL CAPITAN RESERVOIR

DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
82-10-07	1500	.58	520	8.1	21.5	152	19	33	17
83-04-29	1200	154	273	8.1	13.0	86	--	20	8.8

DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)
82-10-07	42	36	1.5	3.6	133	--	51	31	308
83-04-29	21	33	1.0	2.7	82	--	24	23	166

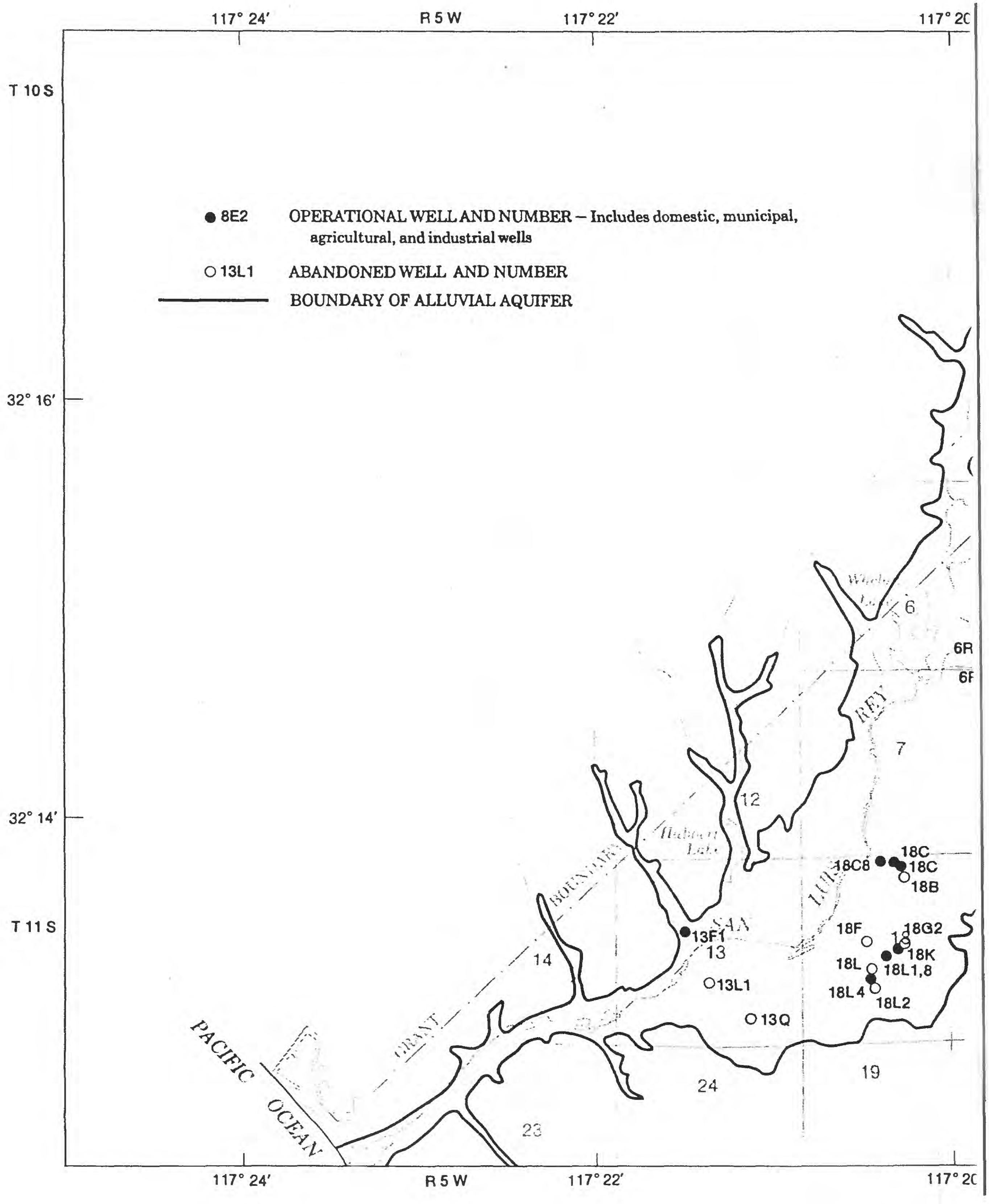
DATE OF SAMPLE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, ORGANIC DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)	BORON, DIS-SOLVED (UG/L AS B)	IRON, DIS-SOLVED (UG/L AS FE)	CARBON, ORGANIC TOTAL (UG/L AS C)
82-10-07	300	<.10	<.060	--	.80	.020	40	22	5.1
83-04-29	169	.21	.070	.33	.40	.050	30	100	7.1

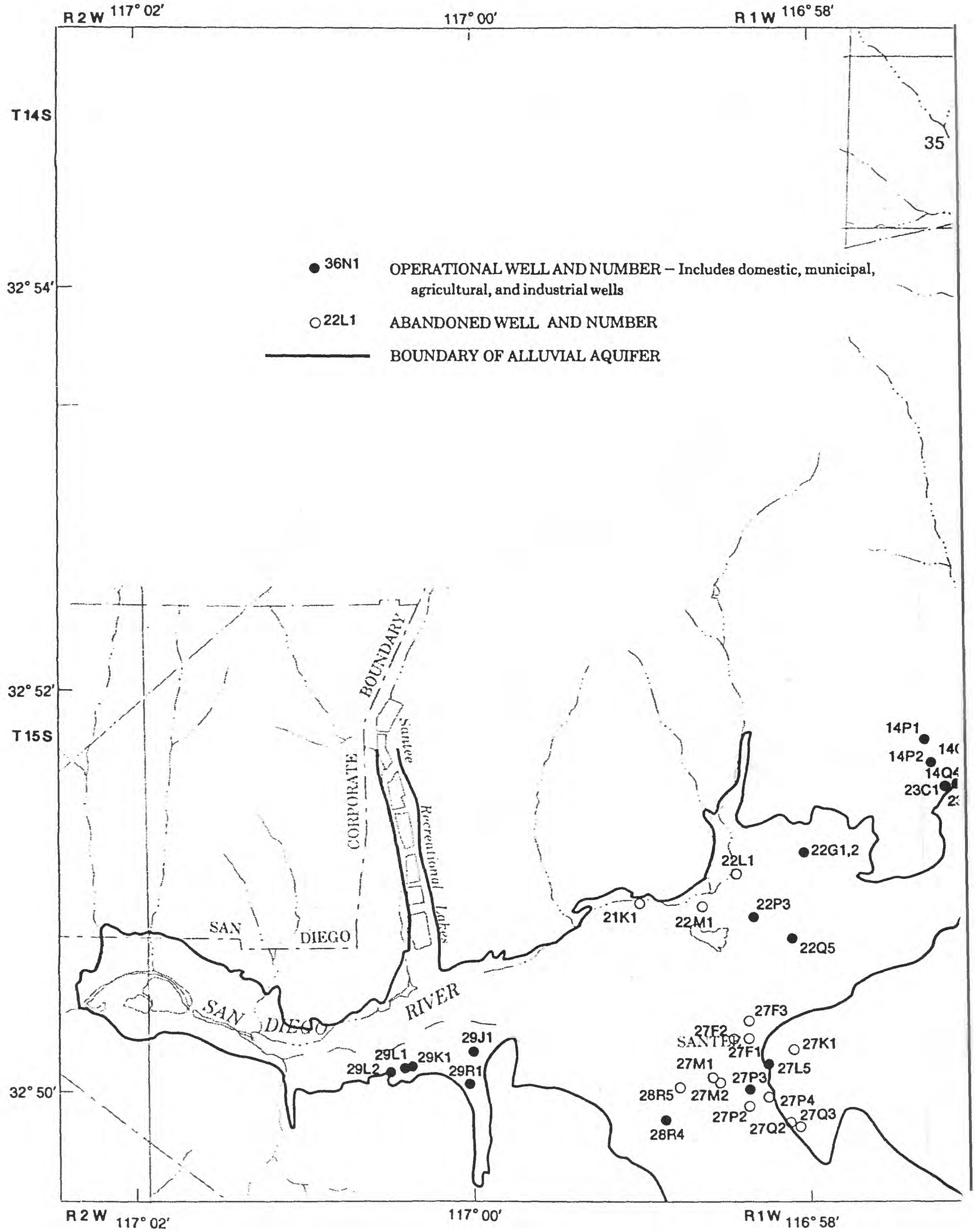
TIJUANA RIVER NEAR NESTOR

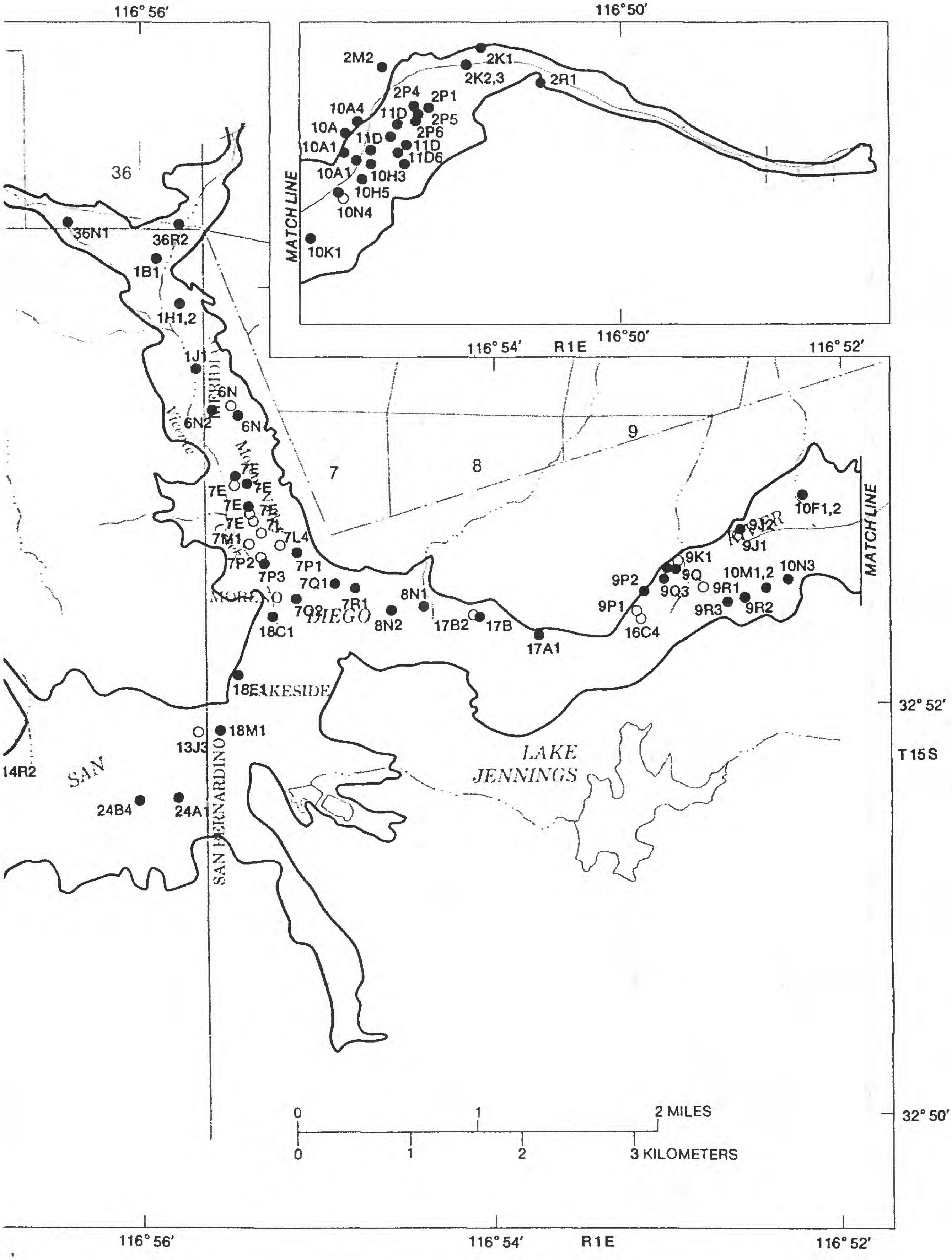
DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
82-10-07	1200	.87	3050	8.2	27.5	650	320	140	73
83-03-16	1200	945	620	8.7	20.5	165	9	38	17

DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)
82-10-07	370	53	6.4	46	327	--	650	27	1850
83-03-16	69	46	2.4	4.0	157	--	83	24	376

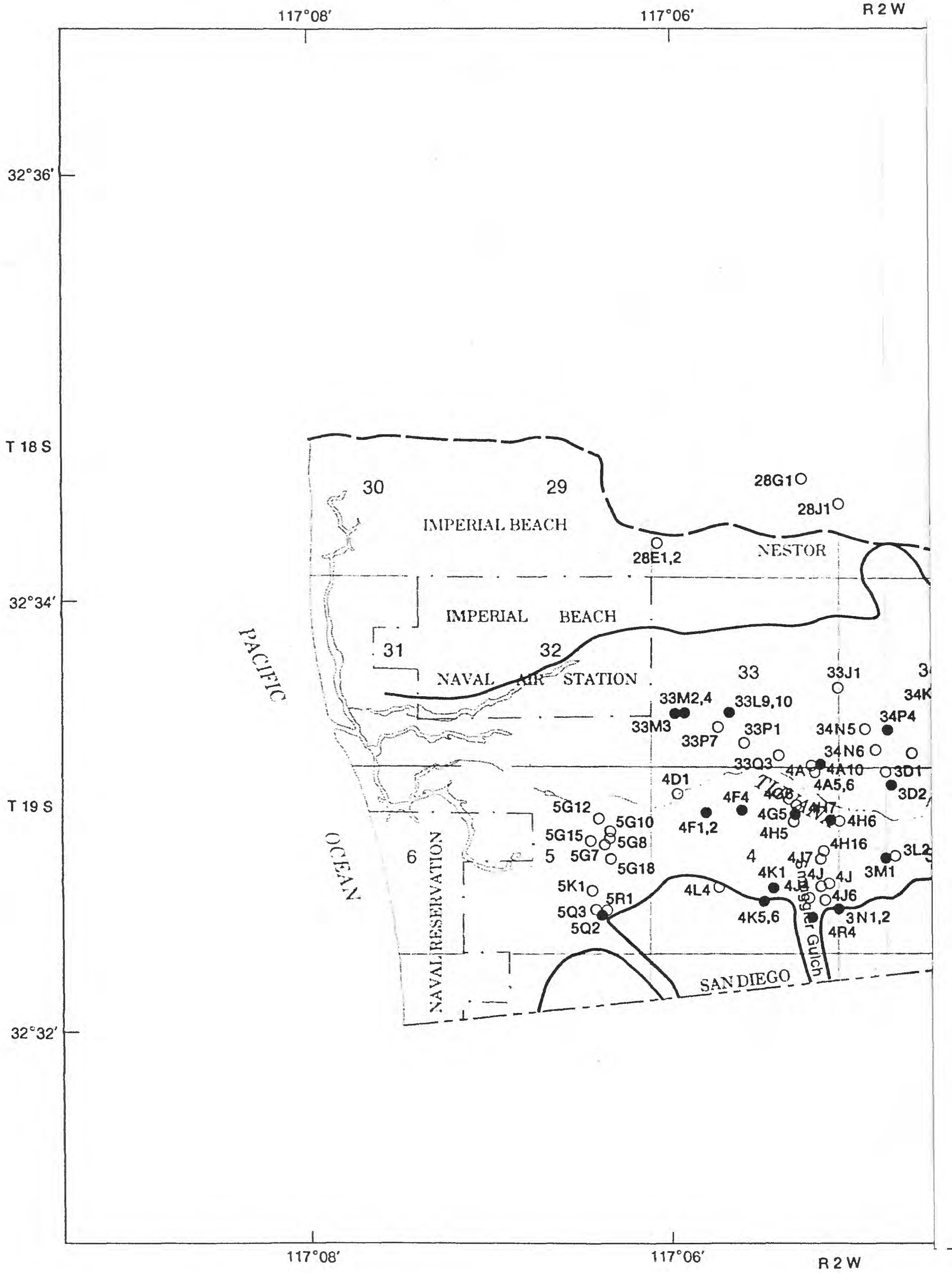
DATE OF SAMPLE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, ORGANIC DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)	BORON, DIS-SOLVED (UG/L AS B)	IRON, DIS-SOLVED (UG/L AS FE)	CARBON, ORGANIC TOTAL (UG/L AS C)
82-10 07	1749	<.10	13.0	34	47	3.50	440	480	40
83-03-16	378	.64	.140	.66	.80	.130	90	20	12


117° 24'
R 5 W
117° 22'
T 10 S
32° 16'
32° 14'
T 11 S
8E2 OPERATIONAL WELL AND NUMBER – Includes domestic, municipal, agricultural, and industrial wells
13L1 ABANDONED WELL AND NUMBER
BOUNDARY OF ALLUVIAL AQUIFER
PACIFIC OCEAN
6
6R
7
12
13
14
19
23
24
18C
18C8
18B
13F1
18F
18G2
18K
18L
18L1,8
18L 4
18L2
13L1
13Q
SAN LUIS REY
BOUNDARY
GRANT


R 2 W 117° 02'
117° 00'
R 1 W 116° 58'
T 14 S
35
32° 54'
36N1 OPERATIONAL WELL AND NUMBER – Includes domestic, municipal, agricultural, and industrial wells
22L1 ABANDONED WELL AND NUMBER
BOUNDARY OF ALLUVIAL AQUIFER
32° 52'
T 15 S
CORPORATE BOUNDARY
Santee Recreational Lakes
SAN DIEGO
SAN DIEGO RIVER
14P1
14P2
14Q4
23C1
22G1,2
22L1
21K1
22M1
22P3
22Q5
27F3
27F2
SANTEE
27F1
27K1
27L5
27M1
27M2
27P3
27P4
27P2
27Q2
27Q3
28R5
28R4
29J1
29L1
29K1
29L2
29R1
32° 50'
R 2 W 117° 02'
117° 00'
R 1 W 116° 58'



URE 33. - Location of wells in the Santee hydrologic subarea sampled by the U.S. Geologlical Survey, autumn 1982 and spring 1983.


117°08′
117°06′
R 2 W
32°36′
T 18 S
32°34′
T 19 S
32°32′
PACIFIC
OCEAN
IMPERIAL BEACH
NESTOR
IMPERIAL BEACH
NAVAL AIR STATION
NAVAL RESERVATION
SAN DIEGO
30
29
31
32
33
6
5
4
28G1
28J1
28E1,2
33J1
33M2,4
33L9,10
33M3
33P7
33P1
34N5
34P4
34N6
33Q3
4A10
4A5,6
3D1
3D2
4D1
4F4
4F1,2
4G5
4H5
4H6
4H16
5G12
5G10
5G15
5G8
5G7
5G18
5K1
5R1
5Q3
5Q2
4L4
4K1
4K5,6
4J6
3N1,2
4R4
3M1
Gulch

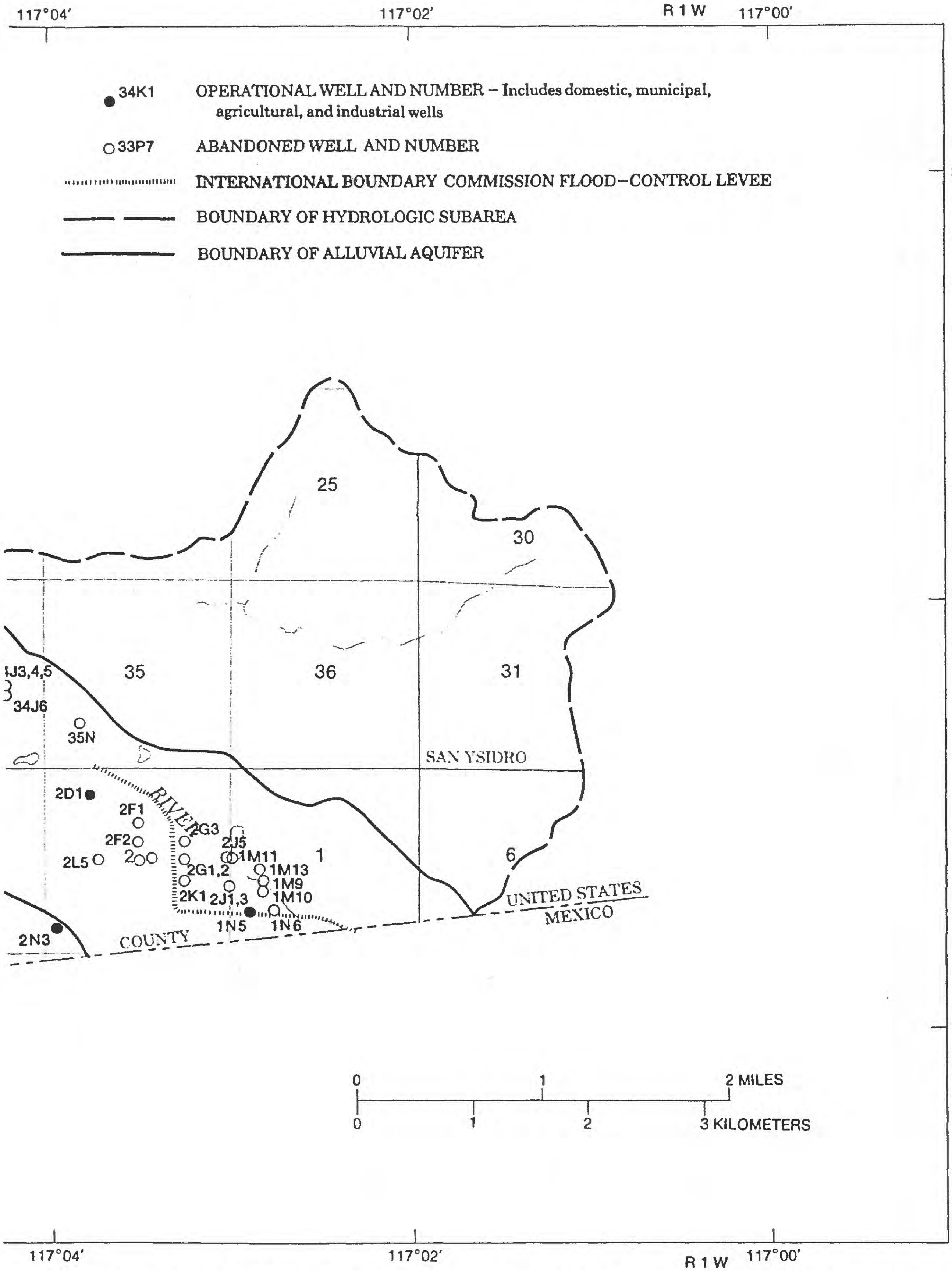


FIGURE 34. - Location of wells in the Tijuana hydrologic subarea sampled by the U.S. Geological Survey, autumn 1982 and spring 1983.